# TENNESSEE DEPARTMENT
# OF
# ENVIRONMENT AND CONSERVATION

## DIVISION OF REMEDIATION
## OAK RIDGE OFFICE

## ENVIRONMENTAL MONITORING REPORT

## For Work Performed:

## July 1, 2020, through June 30, 2021

## August 2022

Tennessee Department of
Environment and Conservation,
Authorization No. 327023

To reach your local
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## ACRONYMS

| | | |
|---|---|---|
| **A** | ASER | Annual Site Environmental Report |
| | aCi | Attocurie |
| **B** | BCK | Bear Creek Station or Bear Creek Kilometer |
| | Benthic Life | Organisms that live on or in the streambed (insects, amphibians, spiders, worms, etc.) |
| | Biocides | Any product or substance used in a cooling tower which is intended to destroy, control or prevent the effects of algae, bacteria, sulfate-reducing bacteria, protozoa, and fungi. |
| **C** | CCME | Canadian Council of Ministers for the Environment |
| | CAA | Clean Air Act |
| | CBSQG | Consensus Based Sediment Quality Guidelines |
| | CERCLA | The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (commonly known as Superfund) enacted by Congress on December 11, 1980. |
| | COCs | Contaminants of Concern |
| | COND | conductivity |
| | $Cr_6$ | Hexavalent Chromium |
| | CRK | Clinch River kilometer |
| **D** | D&D | Decontamination and Decommissioning |
| | DO | Dissolved oxygen |
| | DOE | U.S. Department of Energy |
| | DoR | Division of Remediation |
| | DOR-OR | Division of Remediation – Oak Ridge |
| | DWR | Division of Water Resources |
| **E** | EFPC | East Fork Poplar Creek |
| | EMWMF | Environmental Management Waste Management Facility |
| | EPA | Environmental Protection Agency |
| | EPT | Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) |
| | %EPT – Cheum | Percent EPT - Cheumatopsyche |
| | ESOA | Environmental Surveillance Oversight Agreement |
| | ETTP | East Tennessee Technology Park |
| **F** | FFA | Federal Facilities Agreement |
| | FRMAC | Federal Radiological Monitoring and Assessment Center |
| **G** | GCN | greatest conservation need |
| | GPS | Global Positioning System |
| **H** | $H_2SO_4$ | sulfuric acid |
| | HAs | Health Advisory Values |
| | HCl | hydrochloric acid |

| | | |
|---|---|---|
| | HFIR | High Flux Isotope Reactor |
| | Hg | mercury |
| | $HNO_3$ | nitric acid |
| | HRE | Homogeneous Reactor Experiment |
| **L** | LLW | Low-level radioactive waste |
| | LSC | Liquid Scintillation Counting |
| **M** | MCL | Maximum Contaminant Limit see NPDWR |
| | MDL | Minimum Detection Limit |
| | MeHg | methylmercury |
| | MDC | minimum detectable concentration |
| | MIK | Mitchell Branch kilometer |
| | MQL | Minimum Quantification Limit |
| | MSRE | Molten Salt Reactor Experiment |
| **N** | NNSA | National Nuclear Safety Administration |
| | NAREL | National Air and Radiation Environmental Laboratory |
| | NCBI | North Carolina Biotic Index |
| | NOAA | National Oceanic and Atmospheric Administration |
| | NPDWR | National Primary Drinking Water Regulations |
| | NPL | National Priority List |
| | NRC | Nuclear Regulatory Commission |
| | NSDWR | National Secondary Drinking Water Regulations |
| | NT-5 | Bear Creek Northwest Tributary 5 |
| | NTU | nephelometric turbidity units |
| | NUREG | NRC Regulation |
| **O** | ORAU | Oak Ridge Associated Universities |
| | OREIS | Oak Ridge Environmental Information System |
| | ORNL | Oak Ridge National Laboratory, also known as X-10 |
| | ORP | Oxygen Reduction Potential |
| | ORR | Oak Ridge Reservation |
| | OSL | Optically Stimulated Luminescence Dosimeter |
| | %OC | Percent Oligochaeta and Chironomidae |
| **P** | PCBs | Polychlorinated Biphenyls |
| | PEC | Probable Effects Concentration |
| | PRGs | Preliminary Remediation Goals |
| **Q** | QA/QC | Quality Assurance/Quality Control |
| | QAPP | Quality Assurance Project Plan |
| | QEC | Quality Environmental Containers (Beaver, WI) |
| **R** | RA | Remedial Activities |
| | RADCON | Radiation Control Program |
| | RAIS | Risk Assessment Information System |

| | | |
|---|---|---|
| | RER | Remedial Effectiveness Report |
| | ROD | Record of Decision |
| | RPM | Radiation Portal Monitor |
| | RSLs | Regional Screening Levels |
| **S** | SAIC | Science Applications International Corporation |
| | SAP | Sampling and Analysis Plan |
| | SOP | Standard Operating Procedure |
| | SRS | Southern Research Station |
| | Station | A specific location where environmental sampling or monitoring takes place. |
| | SU | standard units |
| | SD | storm drain |
| | SMCLs | Secondary Maximum Contaminant Levels same as NSDWRs |
| | SWSA | Solid Waste Storage Area |
| **T** | T&E species | State- or Federal-listed threatened and endangered species as protected under the Endangered Species Act of 1973. |
| | TR | Target Risk |
| | Tc-99 | Technetium - 99 |
| | TDEC | Tennessee Department of Environment and Conservation |
| | TDEC-DoR | TDEC-Division of Remediation |
| | TDH | Tennessee Department of Health |
| | TDH-NEL | TN Dept. of Health-Nashville Environmental Laboratory |
| | TNUTOL | Total Nutrient Tolerant |
| | TN AWQC | State of Tennessee Ambient Water Quality Criteria |
| | TS | tree swallows |
| | TWQC | Tennessee Water Quality Criteria |
| | TWRA | TN Wildlife Resources Agency |
| **U** | UEFK | Upper East Fork Creek Kilometer |
| | USDI | U.S. Dept. of the Interior |
| | USEPA | United States Environmental Protection Agency |
| | UV | ultraviolet |
| **V** | VOCs | volatile organic compounds |
| **W** | WAC | Waste Acceptance Criteria |
| | WD | wood duck |
| | WCK | White Oak Creek kilometer |

## UNITS OF MEASURE AND THEIR ABBREVIATIONS

| | |
|---|---|
| °C | degrees Celsius/Centigrade |
| μS/cm | micro-Siemens per centimeter |
| mV | millivolts |
| DO | amount of gaseous ($O_2$) dissolved in water |
| pH | scale of acidity from 0 to 14 |
| μg/L | micrograms per liter (parts per billion) |
| mg/L | milligrams per liter (parts per million) |
| ng/g | nanograms per gram (parts per billion) |
| μg/g | micrograms per gram (parts per million) |
| ppb | parts per billion |
| ppm | parts per million |
| millirem | A millirem is one thousandth of a rem |
| rem | A rem is the unit of effective absorbed dose of ionizing radiation in human tissue, equivalent to one roentgen of X-rays |
| mrem | Abbreviation for millirem which is a unit of absorbed radiation dose |

## EXECUTIVE SUMMARY

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation, Oak Ridge (DoR-OR), submits the annual Fiscal Year 2021 (FY21) Environmental Monitoring Report (EMR) for work conducted during the period of July 1, 2020, through June 30, 2021. This report is submitted in accordance with the terms of the Environmental Surveillance and Oversight Agreement (ESOA) and in support of activities being conducted under the Federal Facilities Agreement (FFA). TDEC DoR-OR participates in independent monitoring and verification sampling as well as oversight of current DOE activities across the Oak Ridge Reservation, to confirm existing DOE project results, to support environmental restoration decisions, to evaluate performance of existing remedies and to investigate the extent and movement of legacy contamination.

This FY2020 EMR presents results for 20 independent projects, originally defined in TDEC's FY2021 Environmental Monitoring Plan (EMP) and subsequently completed over the course of FY2021 period of performance. The Historical Groundwater Trends Project initially proposed in the EMP for this period of performance was delayed until FY22 due to lack of staffing to fully execute, though some historical data compilation and further data management did occur. That work is expected to be completed and reported in future EMRs.

This monitoring report focuses on eight general environmental sampling areas spanning all 3 sites across the ORR as well as the offsite areas as applicable. The focus areas include Radiological Monitoring, Biological Monitoring, Air Monitoring, Surface Water Monitoring, Sediment Monitoring, Groundwater Monitoring, Landfill Monitoring, and Watershed Assessments (Holistic) Monitoring.

Project summaries are provided below.

**Fugitive Radiological Air Emissions**

TDEC conducts independent air sampling at select sites across the ORR and compares those results with air sampling data provided by DOE. TDEC samplers are placed with in the ORR boundaries, with focus on locations where the potential for the release of fugitive airborne emissions may be elevated (e.g., locations of the excavation of contaminated soils, demolition of contaminated facilities, and waste disposal operations, etc.). During FY2021, for all eight ORR monitoring locations, the average concentrations, minus background, were below the federal standards for each radiological isotope measured.

**RadNet Air Monitoring**

RadNet is an EPA lead nationwide program that monitors the nation's air, precipitation, and drinking water to track radiation in the environment. This RadNet Air Monitoring project on the ORR began in August of 1996 and provides radiochemical gross beta analysis of air particulate samples collected twice weekly from five air monitoring stations located near potential sources of radiological air emissions on the ORR.

All the data results collected during this FY21 time period were well below the 1.0 pCi/$m^3$ gross beta value which would trigger further analysis. These samples indicate that ORR activities occurring over this sampling time frame, posed no significant impact to the environment or public health from ORR emissions.

**RadNet Precipitation Monitoring**

Nationwide, the RadNet Precipitation Monitoring Project measures radioactive contaminants that are carried to the earth's surface by precipitation. On the Oak Ridge Reservation (ORR), the RadNet Precipitation Monitoring Project provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations.

For this FY21 period of performance, all of the TDEC DoR-OR precipitation sample results for beryllium-7, cesium-137, cobalt-60, potassium-40, and radium-228 were either below their respective detection limits and/or drinking water regulatory limits used for comparisons.

**Benthic Ecological Community Health**

The health of the benthic macroinvertebrate communities in ORR streams has improved overall since TDEC monitoring began in the 1980's. In the past few years, this improvement has leveled off and stabilized. The 2020 sample results from the Benthic Macroinvertebrate Monitoring Project (reported here) measured similarly to recent year's trends.

Within the Y-12 watershed, East Fork Poplar Creek (EFPC) and Bear Creek (BC), assessment of the benthic communities continue to show impairment at the headwaters closest to DOE facilities and industrial activities. Macroinvertebrate communities do improve downstream as they get farther away from the sources of contamination.

Within the ORNL watershed, White Oak Creek (WOC) and Melton Branch, have remained relatively stable over the past decade, with only slight variation year-to-year.

The ETTP watershed, which includes Mitchell Branch, shows the largest variation in TMI scores from year-to-year. Mitchell Branch is smaller than other streams monitored on the ORR and is more susceptible to both natural and anthropomorphic stressors. In 2020, MIK 0.45 had a sharper decrease in (TMI) than the previous 10 years indicating a trending reduction in overall health for benthic communities in this watershed.

### ORR Roving Creel Survey

This project measured angling efforts at key areas where ORR watersheds drain into publicly accessible waters. Angling activities are measured to gather data to help guide qualitative risk discussions and related assessments. For this project, TDEC-DoR-OR staff interviewed fishermen on the Clinch River and Poplar Creek. Fishermen were asked questions about their current fishing trip. Nineteen percent (19%) of all anglers interviewed in this study were part of commercial recreational fishing charters. Roughly half of all anglers interviewed in this study described themselves as locals, many of whom had fished in these waters previously. This Roving Creel Survey data suggests that there is notable fishing activity near key ORR surface water exit points, with the area immediately downstream from the confluence of White Oak Creek Embayment area and the Clinch River being the most popular among anglers. The area immediately downstream of the confluence of East Fork Poplar Creek and Poplar Creek was the least popular.

### Radiological Uptake in Food Crops

DOE has historically conducted studies on locally grown and harvested food crops and milk to analyze the potential impacts of airborne releases of radiation and the possible effects on food crops consumed by residents of local communities. The scope of this TDEC project was to build on those similar DOE lead projects, with TDEC DoR-OR independent sampling being used to evaluate additional samples or verify and correlate DOE's similar sample results.

Samples collected this FY were very limited due to COVID impacts; however, for this sample set, the TDEC DoR-OR FY 2021 vegetable, hay, and milk sampling results do not indicate that DOE ORR activities are impacting radionuclide concentrations in food crops.

### Offsite Groundwater

This ongoing project assesses offsite groundwater from residential wells located outside the boundaries (downgradient) of the ORR. During FY2021, TDEC did not fully execute this project as planned in the EMP due to sampling restrictions of residences during the COVID pandemic time frame. While full execution of the planned TDEC sampling did not occur, four sample locations were co-sampled by TDEC in conjunction with DOE's offsite sample teams. TDEC's co-sampling included analysis for volatile, radiochemical and metals analyses. For all four of the samples collected by TDEC during FY21, there were no volatile compounds detected in the DOE or TDEC DoR-OR's samples. None of the metals analytical results exceeded regulatory limits and radiochemical results were below levels that would pose unacceptable risk to offsite users of the groundwater. TDEC sample results were comparable to DOEs co-located sampling results at those locations.

**EMDF Surface Water Parameters**

Surface water quality measurements were collected to delineate the current site conditions in the Bear Creek Valley (BCV) watershed. The BCV watershed includes the proposed Environmental Management Disposal Facility (EMDF) area. The EMDF is proposed to dispose of low-level radioactive waste and hazardous waste generated by ORR CERCLA remedial activities from the ORR. TDEC's monitoring of groundwater and surface waters in central BCV, support both the surface water evaluation of the Bear Creek Valley assessment project, as well as providing data that may support current or anticipated future data collection efforts at the central Bear Creek Valley site. The TDEC DoR-OR data collected within this project, complements DOE's BCV surface water monitoring program, and will help ensure that water quality parameters collected as background information for this site will be as robust as possible.

**EMWMF Sampling**

Contaminated materials from CERCLA remediation activities on the ORR are approved for disposal in the existing Environmental Management Waste Management Facility (EMWMF), provided they meet the waste acceptance criteria. TDEC conducts this project in conjunction with DOE's similar project, designed to provide assurance and verification through independent monitoring that contaminants are not migrating from the facility into the environment off site in concentrations above agreed upon limits. TDEC conducts reviews of TDEC's independently collected sample data as well as completes evaluations of DOE's similar sampling data. Reviews are focused on ensuring that operations at the EMWMF remain protective of public health and the environment, and that they meet the associated remedial actions objectives identified in the decision documents associated with this facility.

During FY21, TDEC measured physical water quality parameters at 4 locations and collected surface water samples at the EMWMF-2 (Underdrain) and EMWMF-3 (V-Weir). The TDEC sample results from both EMWMF-2 (Underdrain) and EMWMF-3 (V-Weir), were comparable to DOE's results. At the EMWMF-2 (Underdrain) uranium isotope levels appear to increase very slightly but remain at levels which are well below EPA MCLs. The EMWMF-3 location, (V-Weir) continues to discharge constituents including alpha and beta activity, uranium isotopes, tritium, metal; however, the levels did not violate the EMWMF Record of Decision discharge limits. There were no exceedances at the VWEIR of the Tennessee Ambient Water Quality Criteria (AWQC) for Fish and Aquatic Life.

**Environmental Dosimeters**

The Environmental Dosimeters Project was designed to independently assess impacts from radiation exposure at various locations across the ORR. This FY21 project was part of a long-term monitoring project conducted over the years at the ORR, and historic information from these assessments has shown that the majority of the areas evaluated using this passive monitoring process, posed no potential risk to the public. Similarly, the results of this year's sampling also confirmed no significant changes in dose rates for the 25 locations included in the FY21 monitoring. This dosimetry assessment project was terminated in the third quarter of FY2021, to focus resources in other mission areas. Moving forward, when necessary, radiological surveys will be conducted by TDEC staff at identified areas of concern or interest, using a focused site-specific assessment methodology rather than passive sampling through dosimetry.

**Haul Road Surveys**

Due to COVID-19 site restrictions and TDEC DoR-OR personnel limitations, no ORR Haul Road surveys were conducted by TDEC DoR-OR personnel during FY2021.

**Real Time Measurement of Gamma Radiation**

The Real Time Measurement of Gamma Radiation Project, conducted on the Oak Ridge Reservation (ORR), measures exposure rates at locations where gamma emissions may be expected to fluctuate substantially over relatively short periods of time. During the FY2020 monitoring period, gamma monitors were located at: Fort Loudoun Dam (Background Site), Environmental Management Waste Management Facility (EMWMF), ORNL Central Campus Remediation / Building 3026 Radioisotope Development Lab, Molten Salt Reactor Experiment (MSRE), and the Spallation Neutron Source (SNS). These monitors measure concentrations of gamma radiation in real time, thus allowing for the assessment of conditions at locations where gamma emissions may fluctuate substantially over relatively short periods of time.

During this period of performance, due to scheduled life cycle maintenance of equipment, only six (6) months of data were collected. Over that time, no monitored location exceeded the 2 mrem in anyone-hour period comparison limit. On 1/6/2021, all five instruments were removed from service and returned to the factory for recalibration/inspection/maintenance. No ORR gamma radiological impacts to human health or the environment at these monitored locations during the time frames the gamma meters were deployed were identified during this project.

**Surplus Sales Verification**

Periodically at the request of the ORNL's Excess Properties staff, TDEC DoR-OR performs pre-auction verification surveys on items being auctioned by ORNL's Excess Properties Sales. During FY2021, TDEC DoR-OR surveyed four (4) DOE surplus sales lots. During these visits, 12 items were identified with radiological activities above ambient background levels and were identified to ORNL personnel for follow up if necessary.

**Trapped Sediment (East Fork Poplar Creek)**

The East Fork Poplar Creek (EFPC) Trapped Sediment project focuses sampling and analysis of suspended sediments found in the surface water column. Evaluation of contamination within the suspended sediments allows for assessment of contamination that is found within the mobile sediment load, that is migrating through the monitored exit pathway streams. Trapped sediment was collected in EFPC from the western end of Y-12 to the east at Station 17 (EFK 23.4).

The analysis of sediment collected from the sediment traps in FY2020, identified metals contamination in the suspended sediment that passed location EFK 23.4. In FY2020, cadmium and copper levels were identified in the suspended sediment samples at levels above the threshold effects concentrations (TEC). Mercury levels exceeded the probable effects concentrations (PEC). In FY2021, lead and nickel concentrations were identified above the TEC at levels similar to levels identified in 2015 and 2016. When a metal occurs at a concentration above the TEC, a possibility of impairment to benthic macroinvertebrate populations is possible. Above the PEC, it is probable that these populations will be impaired. In addition to the metals identified at EFK 23.4, gross alpha and beta radionuclide activities were also identified in suspended sediment samples, at levels above ambient background. The uranium metals analysis identified uranium-234, uranium-235, and uranium-238 results at greater radioactivity than identified at the background site. Some naturally occurring gamma radionuclides were detected; however, their activity was similar to the background site; thus, gamma radioactivity is not identified as a concern at EFK 23.4 at this time.

**Rain Event**

As remedial actions, contaminated soil excavations, and other demolition activities occur throughout the ORR, precipitation water can fall on contaminated areas, accumulate in excavation pits, trenches, basins, sumps, basements, or otherwise impact soil remediation activities. That precipitation has the potential to become contaminated through that contact and then be dispersed into the environment through stormwater runoff. The goal of this project is to obtain independent data to determine if DOE ORR's best management practices (BMPs) which are employed at sites undergoing remedial action across the ORR, are preventing offsite releases of legacy contaminants. During FY2021, TDEC DoR-OR reviewed and provided comment on documents related to D&D work, co-sampled with DOE to monitor releases of legacy CERCLA contaminants into the environment, observed D&D and RA sampling activities, and reviewed DOE sampling results to ensure compliance with negotiated and agreed to release criteria. Currently, DOE employs a comprehensive storm water monitoring program at ORR RA sites to monitor such potential migration of contamination offsite. TDECs project independently assesses those activities, and the potential for unintended stormwater related CERCLA contamination migration.

During FY21 POP no significant finding were identified and TDEC data sets were similar to those collected in DOE co-samples.

**Accumulated Water Discharge**

This project complements the Rain Event project described above. This project monitors accumulated water at sites with ongoing CERCLA D&D and/or RA operations. For FY2021, those projects included the Y-12 Outfall-200 Mercury Treatment Facility headworks construction and the ORNL Molten Salt Reactor Experiment's basement groundwater sump and that sump's associated free-released water. TDEC DoR-OR reviewed pertinent DOE sampling data, observed DOE sampling and monitoring activities, and co-sampled as appropriate to confirm that relevant treatment and discharge criteria were met.

TDEC DoR-OR's oversight of DOE's subcontracted activities at the Y-12 Outfall 200 Mercury Treatment Facility identified that the sample collection protocols used by the sampling team, were properly followed per their respective SOPs. Review of the analytical sample results identified that the level of mercury in the accumulated water increased over the course of the facility's operation. This increase was especially evident in 2021. The increase in mercury concentrations in the accumulated water, aligned with the contractors' efforts to lower the groundwater level around the facility area.

**Ambient Surface Water Parameters**

In an effort to both complement and verify the DOE environmental program, and to ensure that the citizens and environmental resources of Tennessee are not potentially impacted by surface water contamination, this Ambient Surface Water Parameter Project has been implemented in some capacity each year by TDEC DOR_OR, since 2005. This project aims to assess the degree of surface water impacts, by monitoring streams and collecting monthly sampling data to establish and build a comprehensive database of physical stream parameters (conductivity, pH, temperature, and dissolved oxygen) for surface water bodies around the reservation.

In FY2021, on a monthly basis, the primary water quality parameters (specific conductivity, pH, temperature, and dissolved oxygen) were measured at three ORR exit pathway streams: East Fork Poplar Creek, Bear Creek, and Mitchell Branch. Of these measurements, all readings collected during the FY21 POP were within the State of Tennessee Water Quality Criteria (TDEC, 2019). While there is no existing State of Tennessee Water Quality Criteria for conductivity, it can be a general indicator of water quality and is also evaluated regularly. Bear Creek site BCK 12.3 was found to have statistically significantly higher conductivity readings than all other streams sampled this POP. Despite the higher conductivity, historical data (2005-2021) suggests that BCK 12.3 has had a decreasing conductivity trend over time of roughly 32 μS/cm annually since 2005. On East Fork Poplar Creek, site EFK 23.4 has shown a steadily increasing trend of conductivity which is on average roughly 8 μS/cm annually. The reason(s) for these trends have not yet been determined.

**Ambient Surface Water Sampling**

An ambient surface water sampling project has been implemented by TDEC each year since 1993. DOE has also implemented a surface water monitoring program for several years that consists of sample collection and analysis along the Clinch River (DOE, 2017; DOE, 2019). While the current DOE project solely sampled the Clinch River, this complementary TDEC DoR-OR project builds upon DOE's sampling by looking at specific exit-pathway streams that flow into the Clinch River. These exit pathway streams include the ORR's Bear Creek (BC) and East Fork Poplar Creek (EFPC) as well as an offsite background stream Clear Creek (CC). Samples and flow measurements were taken at these streams quarterly with the intent to provide an evaluation of the potential loading of contaminants at each of these stations.

Analysis of the data provided contaminate flux values to provide an approximated mass per year of contamination potentially loaded at each site. Of specific interest during this POP were mercury and uranium.

Location EFK 25.1 had the highest flux of mercury past that site, based on available data for FY21. Surface water at EFK25.1 potentially loads an approximated 1 kilogram of mercury each year past the site location. This load value decreases downstream to nearly 0.5 kg/year at EFK 6.3. Mercury analyzed in surface water samples collected on EFPC during this POP yielded concentrations above the TN criterion for water and organisms of 0.05 μg/L. Upstream sections of EFPC yielded concentrations nearing 1.1 μg/L, or nearly 21 times the TN criterion. At Clear Creek kilometer 1.6, surface water loads approximately 1 gram of mercury past that site each year.

Bear Creek mercury concentrations were all below the Tennessee AWQC criteria for organisms and water.

Uranium flux was approximated for each stream location during this POP. In these analyses, Bear Creek yielded high uranium concentrations at upstream locations (near Y-12) with concentrations upwards of 220 µg/L. Bear Creek generally has higher concentrations of uranium, but has a lower flow, resulting in from 26.8 kg to 63.9kg per year of uranium mass passing those BCK sampling sites. While Bear Creek sampling concentrations were higher, East Fork Poplar Creek may potentially pass a larger mass of uranium by each site due to its higher flow. Sampling results collected in FY21 at EFPC indicate that an approximated 100 kilograms of uranium pass through East Fork Poplar Creek each year at the most downstream sampled location (EFK 6.3). The reference stream, Clear Creek, has a flux of only 0.2 kilograms of uranium each year.

The Clinch River itself was also analyzed during this POP at several locations, through co-sampling with DOE. TDEC co-sampled at all of the DOE Clinch River (CR) sites (i.e. CRK 16, 32, 58, 66). As is DOE procedure with their project, all sites were compared to criteria defined by EPA and the state of Tennessee to determine stream impact (EPA, 2009; TDEC, 2019). All of the CR metal and radiological analytical results were below criteria limits.

### White Oak Creek Radionuclides

Similar to the Ambient Surface Water Sampling project above that evaluated Bear Creek and East Fork Poplar Creek during this POP, this project was designed to evaluate the high strontium-90 (Sr-90) concentrations previously identified at site CRK 33.5. Site CRK33.5 is the White Oak Creek (WOC) and Clinch River confluence. This project seeks to continue the assessment regarding ongoing discharges of Sr-90 and other radiological inputs into the Clinch River from White Oak Creek specifically.

Surface water samples were collected quarterly at four sites on WOC and one on the Clinch River (CR). All were analyzed for strontium-89/90. Results identify low levels of strontium-89/90 at site WCK 6.8 (the upgradient portion of the creek above the ORNL facility), and increasing concentrations at ECK 3.9, WCK 3.4 and WCK 2.3 with in the ORNL footprint. A lower but still elevated concentration of Sr-90 was identified in samples collected at the CRK 33.5 location at the confluence of WOC and CR. This project assessment is designed to help quantify the contribution of Sr-90 from White Oak Creek to the Clinch River at the WOC confluence only and has not assessed impacts further within the Clinch River itself at this time.

## Watershed Assessments (Holistic) Monitoring: Bear Creek Valley

Initiated in FY2020, this project was designed as a holistic assessment of the Bear Creek Valley Watershed, specifically to provide a snapshot of the complete environmental health of the Bear Creek watershed at this point in time. Initially an extensive historical records review, preliminary sampling, and data gap analysis was completed. In this FY2021, Phase 2 field sampling of surface water, sediment, soils, vegetation, toxicity, fish, benthic macroinvertebrates, and other biota (bird eggs, insects, spiders, and crayfish) at Bear Creek kilometers (BCK) 3.3, BCK 4.5, BCK 7.6, BCK 9.6, and BCK 12.3, were conducted. The preliminary result of that sampling is as follows.

- In Bear Creek's sediments, uranium is the primary metal of concern.
- In the surface water nitrate and uranium are the primary contaminants of concern.
- The soils sampled for this project identified no SVOC exceedances or pesticides, with arochlor 1260 detected in each of the Bear Creek Soils sampling sites, but below the EPA RSLs for residential soil under the direct contact exposure scenario. Arsenic and uranium were detected in all the soil samples at levels above their respective RSLs. At BCK 11.97, the mercury concentration exceeded that RSL. At the Bear Creek sites, cadmium was considerably higher than the background location, but fell below its RSL for soil direct contact. Several PFAS compounds were detected in all the BCK soil samples at very low levels below the EPA RSL (THI=1) for PFOS. Uranium and its radionuclide daughters contribute to relatively high gross alpha soil values at the Bear Creek soil sampling sites with site BCK 7.87 exhibiting an elevated gross beta activity (28.4 pCi/g), above the background level (17.7 pCi/g).
- Surface water toxicity sampling (i.e. preliminary whole effluent toxicity (WET) testing) of Bear Creek surface water showed that reproduction of *Ceriodaphnia dubia* (water flea) was inhibited at BCK 12.3. However, at the other sites, survival and reproduction of *Ceriodaphnia dubia* were not inhibited. The *Pimephales promelas* (fathead minnow) was also used for WET testing survival and growth at the same sampling sites. Inhibition in these samples was demonstrated at three sites. The worst performing site was EFK 2.2 which is located at the mouth of Bear Creek, where the IC25 score was 21.8% (growth) and 56.3% (survival) for samples collected in November 2020. Follow-up toxicity sampling is planned to verify these results.
- The benthic macroinvertebrate sampling for these sites showed that at locations BCK 12.3 and BCK 9.6 there is slight impairment in terms of supporting a healthy benthic community. All of the Bear Creek sites from BCK 7.6 and further downstream were non-impaired.

Final data gap sampling will conclude this project in FY22 / FY23 and final watershed level reporting of final results will be available under separate cover.

# 1.0 INTRODUCTION

## 1.1 PURPOSE OF THE ENVIRONMENTAL MONITORING REPORT (EMR)

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation Oak Ridge Office (DoR-OR), submits its annual (FY2022) Environmental Monitoring Report (EMR) for the period July 1, 2020, through June 30, 2021, in accordance with the terms of the Environmental Surveillance and Oversight Agreement (ESOA) and in support of activities being conducted under the Federal Facilities Agreement (FFA).

The Environmental Surveillance Oversight Agreement (ESOA) is designed to assure the citizens of the State of Tennessee that the Department of Energy's (DOE) current activities in Oak Ridge, Tennessee, are being performed in a manner that is protective of their health, safety, and environment. Through a program of independent environmental surveillance oversight and monitoring, the State advises and assesses DOE's environmental surveillance program. Working collaboratively with the Office of Science, National Nuclear Safety Administration (NNSA), and DOE Environmental Management, the State conducts independent monitoring and verification as well as project reviews, and if applicable, suggests modifications to current activities.

TDEC DoR-OR personnel, in support of the tri-party (EPA, TDEC, and DOE) Federal Facilities Agreement (FFA), also conduct independent environmental monitoring to ensure legacy contamination is managed appropriately. Monitoring conducted under the FFA supports environmental restoration decisions, evaluates performance of existing remedies, and investigates the extent and movement of legacy contamination. TDEC DoR-OR will take appropriate actions to identify, prevent, mitigate, and abate the release or threatened release of hazardous substances, pollutants, or contaminants from the ORR which may pose an unacceptable risk to human health or the environment for the State of Tennessee.

DOE and the State, in a spirit of partnership and cooperation, are committed to assure DOE's Oak Ridge activities are performed in a manner that is protective of health, safety, and the environment. This document provides an annual summary report for the FY2021 monitoring and assessment projects conducted by TDEC DoR-OR during this period of performance.

## 1.2 OBJECTIVE

The objective of the TDEC DoR-OR Environmental Monitoring Program is to provide a comprehensive and integrated monitoring and surveillance program for all media (i.e. air, surface water, soil, sediment, groundwater, drinking water, food crops, fish and wildlife and biological systems), as well as the emissions of any materials (hazardous, toxic, chemical, or radiological) on the ORR and its surrounding environment. These projects are also used to evaluate the effectiveness of the DOE environmental monitoring program, by collecting data to verify DOE data sets.

This FY2021 EMR presents the results of twenty (20) independent projects proposed in the FY2020 Environmental Monitoring Plan (EMP) and completed throughout FY2021. This monitoring report focuses on the following nine (9) general areas: Air Monitoring, Biological Monitoring, Groundwater Monitoring, Landfill Monitoring, Radiological Monitoring, Sediment Monitoring, Storm Water / Water Discharge Monitoring, Surface Water Monitoring, and Watershed Assessment (Holistic) Monitoring.

## 1.3 THE OAK RIDGE RESERVATION

The Oak Ridge Reservation (ORR) is comprised of three major facilities:

- East Tennessee Technology Park (ETTP), formerly K-25
- Oak Ridge National Laboratory (ORNL), formerly X-10
- Y-12 National Security Complex (Y-12)

Facilities at these sites were constructed initially as part of the Manhattan Project. The ORR was established for the purposes of enriching uranium for nuclear weapons components and pioneering methods for producing and separating plutonium. In the 70 years since the ORR was established, a variety of production and research activities have generated numerous radioactive, hazardous, and mixed wastes. These wastes, along with wastes from other locations, have been, and are being, disposed of on the ORR.

The primary missions of the three ORR facilities have evolved and continue to evolve to meet the changing research, defense, and environmental restoration needs of the United States. Current operations, like historical operations before them, continue to perform missions that have the potential to impact human health and the environment.

The Oak Ridge National Laboratory (ORNL) conducts leading-edge research in advanced materials, alternative fuels, climate change, and supercomputing. ORNL's activities of fuel reprocessing, isotopes production, waste management, radioisotope applications, reactor developments, and multi-program laboratory operations have produced waste streams that have resulted in environmental releases that contain both radionuclides and hazardous chemicals.

The Y-12 National Security Complex (Y-12) continues to be vital to maintaining the safety, security, and effectiveness of the US nuclear weapons stockpile and reducing the global threat posed by nuclear proliferation and terrorism. Residual waste streams from operational processes at this site have resulted in environmental releases that contain both radionuclides as well as hazardous chemicals.

The East Tennessee Technology Park (ETTP), a former uranium enrichment complex, is being transitioned into an industrial technology park. Even though the gaseous diffusion activities at ETTP have concluded, residual environmental waste streams and current decommissioning activities have resulted in environmental releases that contain both radionuclides and hazardous chemicals.

In accordance with the ESOA Agreement, the FFA Agreement, and the TDEC mission statement, TDEC DoR-OR shall work to assure the citizens of Tennessee that the DOE's activities on and around the ORR, Oak Ridge, Tennessee, are being performed in a manner protective of human health and the environment.

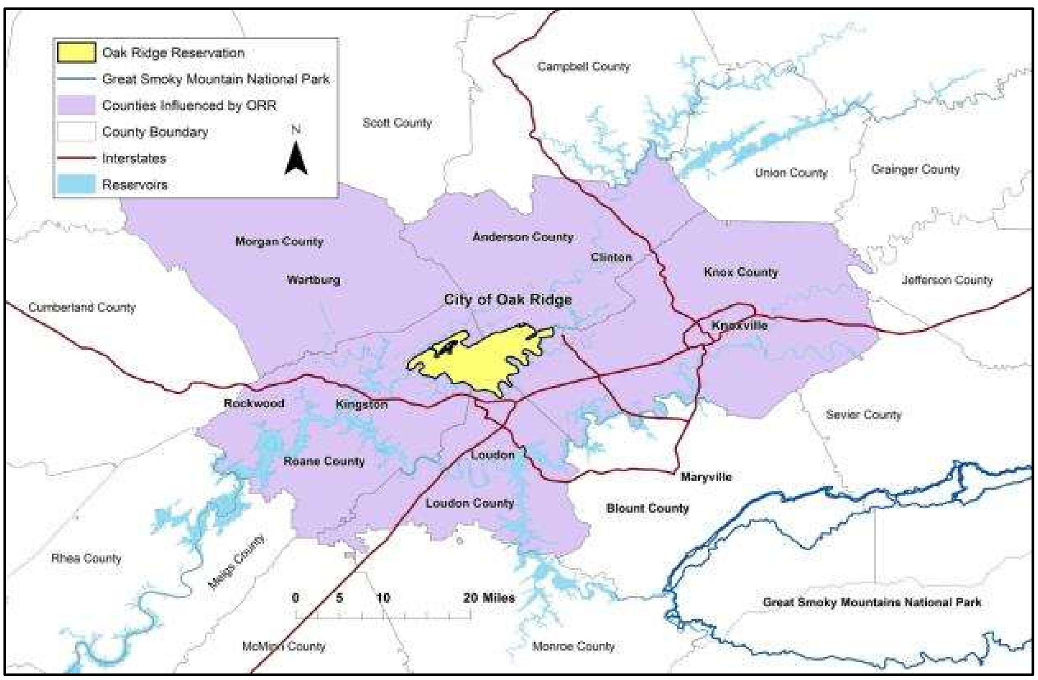



**Figure1.3.1: Location of the Oak Ridge Reservation in Relation to Surrounding Counties**

## 1.3.1 Geography of the ORR Area

Located in the valley of East Tennessee, between the Cumberland Mountains and the Great Smoky Mountains, the ORR is bordered partly by the Clinch River. The ORR is located in the counties of Anderson and Roane, and within the corporate boundaries of the city of Oak Ridge, Tennessee. The reservation is bound on the north and east by residential areas of the city of Oak Ridge and on the south and west by the Clinch River. Counties adjacent to the reservation include Knox to the east, Loudon to the southeast, and Morgan to the northwest.

Portions of Meigs and Rhea counties are immediately downstream from the ORR on the Tennessee River. The nearest cities are Oak Ridge, Oliver Springs, Clinton, Kingston, Harriman, Farragut, and Lenoir City. The nearest metropolitan area, Knoxville, lies approximately 20 miles to the east.

The ORR encompasses approximately 32,500 acres of mostly contiguous land of alternating ridges and valleys of southwest-to-northeast orientation. The Valley and Ridge Province is a zone of complex geologic structures dominated by a series of thrust faults. In general, sandstones, limestones, and dolomites underlie the ridges that are relatively resistant to erosion. Weaker shales and more soluble carbonate rock units underlie the valleys. Winds within the valleys can differ substantially in speed and direction from the winds at higher elevation.

### 1.3.2 Climate of the ORR Area

The climate of the ORR region is classified as humid and subtropical; and is characterized by a wide range of seasonal temperature changes between the summer and winter months. According to the DOE 2021 RER, the "total average rainfall in the ORR area during FY 2020 was 75.9 in. based on a composite of four rain gauge stations located throughout the ORR and one located in Oak Ridge. The total rainfall during FY 2020 was approximately 20 in. more than the 56 in. determined as the 30-year moving average of rainfall measured in the City of Oak Ridge."

The Great Valley of East Tennessee (its shape, size, depth, and orientation), the Ridge-and-Valley physiography contained therein, the Cumberland Plateau, the Cumberland Mountains, and the Great Smoky Mountains all represent major landscape features that affect the wind flow regimes of Eastern Tennessee. Both the local terrain (for example: lithologic rock types in the subsurface and wind-directing regional landforms) as well as the regional climate (rainfall, etc.) are factors in determining the potential migration of contamination from the ORR to the surrounding areas.

### 1.3.3 Population of the ORR Area

More than 1 million citizens reside in the counties immediately surrounding the ORR. Knoxville is the major metropolitan area near Oak Ridge. Except for Knoxville, the land is semi-rural. The area is used primarily for residences, small farms, and pastures. Fishing, hunting, boating, water skiing, and swimming are popular recreational activities in the area.

## 1.4 TENNESSEE'S COMMITMENT TO THE CITIZENS OF TENNESSEE

In accordance with the ESOA Agreement, the FFA Agreement, and the TDEC mission statement , TDEC DoR-OR will work to assure the citizens of Tennessee that the DOE's historic and current activities on and around the Oak Ridge Reservation (ORR), Oak Ridge, Tennessee, are being managed or performed in a manner protective of human health and the environment.

# 2.0 AIR MONITORING

## 2.1 FUGITIVE RADIOLOGICAL AIR EMISSIONS

### 2.1.1 Background

The K-25 Gaseous Diffusion Plant, now called ETTP, began operations in World War II as part of the Manhattan Project. Its original mission was to produce uranium enriched in the 235 isotope (U-235) for use in the first atomic weapons and later to fuel commercial and government owned reactors. The plant was permanently shut down in 1987. Because of operational practices and accidental releases, many of the facilities scheduled for decontamination and decommissioning (D&D) at East Tennessee Technology Park (ETTP) are contaminated to some degree. Uranium isotopes are the primary contaminants, but technetium-99 and other fission and activation products are also present due to the periodic processing of recycled uranium obtained from spent nuclear fuel.

The Y-12 National Security Complex (Y-12) was also constructed during World War II to enrich uranium in the U-235 isotope, in this case by the electromagnetic separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, to conduct lithium-mercury enrichment operations, to manufacture components for nuclear weapons, to dismantle nuclear weapons, and to store enriched uranium.

Construction of the Oak Ridge National Laboratory (ORNL) began in 1943. While the initial mission of the K-25 and Y-12 plants was the production of enriched uranium, ORNL's mission focused on reactor research and the production of plutonium as well as other activation and fission products, which were chemically extracted from uranium irradiated in ORNL's Graphite Reactor and later at other ORNL and Hanford reactors. During early operations, leaks and spills were common and associated radioactive materials were released from operations as gaseous, liquid, and solid effluents, with little or no treatment (ORAU, 2003).

### 2.1.2 Problem Statements

- Many of the facilities at ETTP, Y12, and ORNL scheduled for decommissioning and demolition (D&D) are contaminated. D&D operations at these facilities, as well as the placement of waste from these facilities at the Environmental Management Waste Management Facility (EMWMF), can result in fugitive (non-point source) dispersal of contaminated constituents. This dispersion is aided by winds that tend to blow up the Tennessee Valley (northeast) in the daytime and then reverse direction by blowing down the Tennessee Valley (southwest) at night.

- At ETTP, uranium isotopes are the primary contaminants, but technetium-99 and other fission and activation products are also present, due to the periodic processing of recycled uranium obtained from spent nuclear fuel from offsite.

- Many of the facilities at ORNL are contaminated with a long list of fission and activation products in addition to uranium and plutonium isotopes. Some of these facilities are considered the highest risk facilities at ORNL due to their physical deterioration, the presence of loose contamination, and their close proximity to pedestrian, vehicular traffic, privately funded facilities, and active ORNL facilities.

- At Y-12, facilities contaminated with various isotopes of uranium are scheduled for D&D.

- Much of the material from D&D activities on the Oak Ridge Reservation (ORR) is disposed at EMWMF.

### 2.1.3 Goals

- To protect human health and the environment, TDEC DoR-OR conducts independent air sampling and compares the results with air sampling data provided by U.S. Department of Energy (DOE) to verify DOE's ORR activities are not adversely impacting the public.

- TDEC-DoR-OR personnel review the air monitoring sections of the DOE ORR Environmental Monitoring Plan (EMP) and suggest relevant revisions to the DOE EMP.

### 2.1.4 Scope

TDEC DoR-OR conducted continuous fugitive radiological air emissions monitoring to evaluate DOE's compliance with Clean Air Act (CAA) regulatory standards to ensure potential DOE ORR radiological emissions would not potentially cause a member of the public to receive an effective dose greater than 10 millirem (mrem) in one year, specifically in the areas of remedial and/or waste management activities. Sampler locations were selected with a bias to maximize the likelihood of collecting representative samples from potential sources of airborne contamination.

### 2.1.5 Methods, Materials, Metrics

Eight high-volume air samplers were used in this project. One was stationed at Fort Loudoun Dam in Loudon County to collect background data for comparison while the remaining samplers were placed at ORR locations where the potential for the release of fugitive airborne emissions is greatest (locations of the excavation of contaminated soils, demolition of contaminated facilities, and waste disposal operations).

Each of the air samplers used an 8x10-inch, glass fiber filter to collect particulates from air as it was drawn through the unit at a rate of approximately 35 cubic feet per minute. To ensure accuracy, airflow through each sampler was calibrated quarterly, using a Graseby General Metal Works variable resistance calibration kit.

Samples were collected from each sampler weekly and composited every four weeks then analyzed at the State of Tennessee's Environmental Laboratory.

To assess the concentrations of the contaminants measured for each location, results from each station were compared with the background data and the standards provided in the Clean Air Act. Associated findings were supplied to DOE and its contractors when requested.

Sampling locations were selected for areas with D&D, waste disposal, or current operations that could conceivably violate the 10 millirem radiological limit.

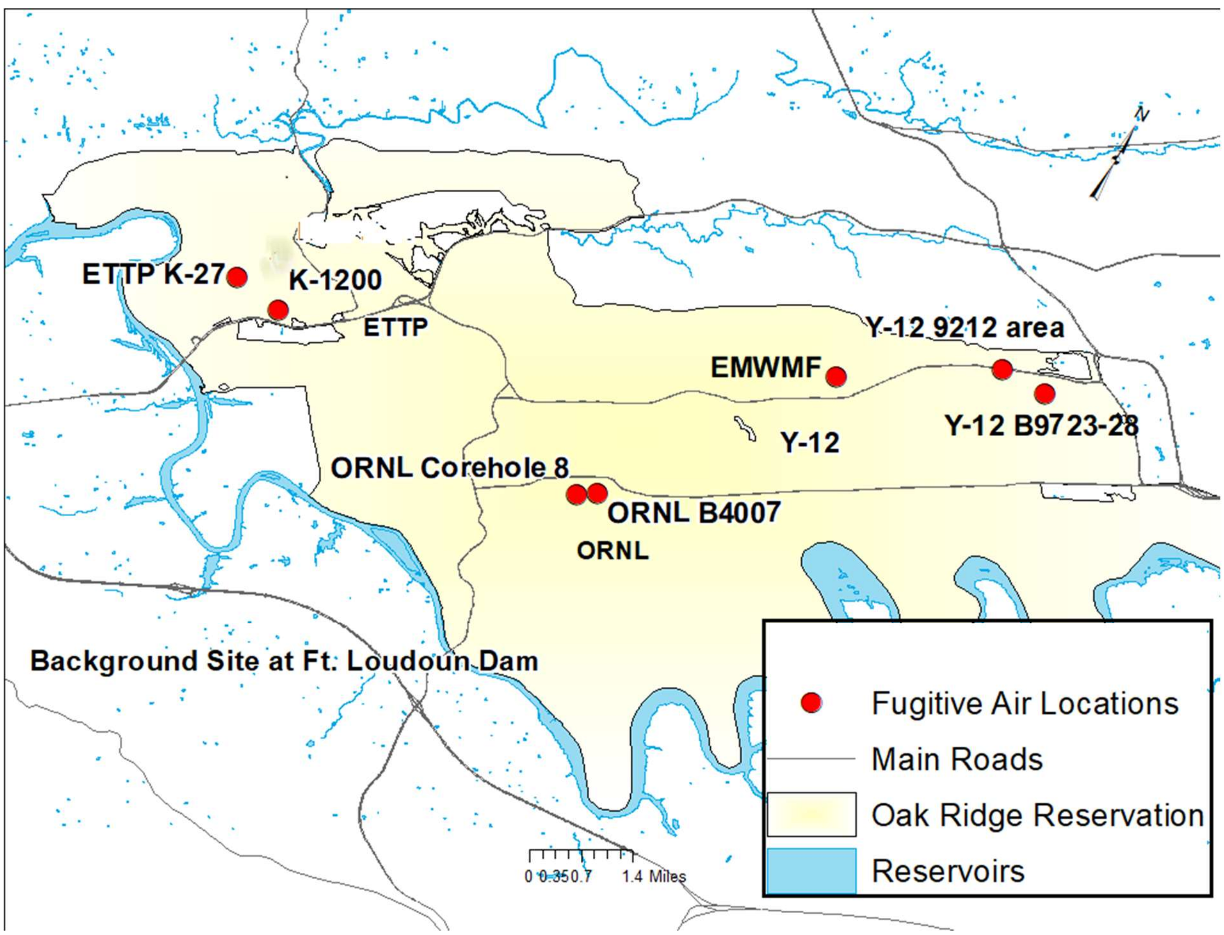



**Figure 2.1.1: Fugitive Air Monitoring Locations**

## 2.1.6 Deviations from the Plan

The original project plan was to collect and report on data through June 2021. Station number K1200 was discontinued after three sampling intervals of four weeks each due to completion of building K1200 and related work in that area. The sampler was then moved to Y-12 East near the biology building which was scheduled for D&D and was operated at that location for eight intervals of four weeks each. Laboratory analysis of the remaining locations was only available through May 05, 2021, consisting of 11 four weeks composites.

## 2.1.7 Results and Analysis

**East Tennessee Technology Park**

Two radiological air monitors were used at ETTP, the site of the original K-25 Gaseous Diffusion Plant. K1200 was discontinued after 12 weeks of sampling as noted above, but K-27 operated for the entire sampling year.

Analyses for the air samples collected from air monitors at ETTP included three isotopes of uranium (U-234, U-235, U-238) and technetium-99 (Tc-99) as shown in Tables 2.1.1 and 2.1.2.

Table 2.1.1 shows the results from the samples taken at ETTP K1200. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 2.1.1: ETTP K1200 Air Monitoring Average Results (pCi/m$^3$)**

| K1200 Sampling Area | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average 7/28/2020 to 9/23/2020 | 5.60E-05 | 6.43E-06 | 4.83E-05 | 3.35E-04 | |
| Average background | 5.07E-05 | 5.70E-06 | 5.37E-05 | 3.31E-04 | |
| Net Activity (Avg. minus background) | 5.33E-06 | 7.33E-07 | -5.33E-06 | 4.33E-06 | |
| 40CFR Part 61 Limit, Appendix E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | 6.93E-04 | 1.03E-04 | -6.43E-04 | 3.10E-05 | 1.84E-04 |

Table 2.1.2 shows the results from the K-27 area sampling location. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 2.1.2: ETTP K-27 Air Monitoring Average Results for (pCi/m$^3$)**

| K-27 Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average 07/01/2020 to 05/05/2021 | 4.64E-05 | 4.55E-06 | 4.23E-05 | 3.21E-04 | |
| Average background | 4.61E-05 | 7.08E-06 | 4.45E-05 | 3.84E-04 | |
| Net Activity (Avg. minus background) | 2.82E-07 | -2.54E-06 | -2.21E-06 | -6.25E-05 | |
| 40CFR Part 61 Limit, Appx. E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | 3.66E-05 | -3.57E-04 | -2.66E-04 | -4.46E-04 | -1.03E-03 |

### Y-12 National Security Complex

Three samplers were used at Y-12. Analyses for the air samples collected from air monitors at Y-12 included three isotopes of uranium (U-234, U-235, U-238) and Tc-99.

Table 2.1.3 shows the results from the samples taken at the building 9212 area of Y-12. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 2.1.3: Y-12 Building 9212 Area Air Monitoring Average Results (pCi/m$^3$)**

| Y-12 9212 Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average 07/01/2020 to 05/05/2021 | 2.51E-04 | 2.29E-05 | 6.72E-05 | 3.69E-04 | |
| Average background | 4.61E-05 | 7.08E-06 | 4.45E-05 | 3.84E-04 | |
| Net Activity (Avg. minus background) | 2.05E-04 | 1.58E-05 | 2.26E-05 | -1.46E-05 | |
| 40CFR Part 61 Limit, Appendix E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | 2.66E-02 | 2.22E-03 | 2.73E-03 | -1.05E-04 | 3.14E-02 |

Table 2.1.4 shows the results from the samples taken at the building 9723-28 area of Y-12. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 2.1.4: Y-12 Building 9723-28 Area Air Monitoring Average Results (pCi/m$^3$)**

| Y-12 B9723-28 Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average 07/01/2020 to 05/05/2021 | 7.91E-06 | 2.73E-06 | 5.55E-06 | 1.27E-04 | |
| Average background | 4.61E-05 | 7.08E-06 | 4.45E-05 | 3.84E-04 | |
| Net Activity (Avg. minus background) | -3.82E-05 | -4.35E-06 | -3.90E-05 | -2.57E-04 | |
| 40CFR Part 61 Limit, Appx. E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | -4.96E-03 | -6.13E-04 | -4.70E-03 | -1.83E-03 | -1.21E-02 |

Table 2.1.5 shows the results from the samples taken at the East area of Y-12. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 2.1.5: Y-12 East Area Air Monitoring Average Results (pCi/m$^3$)**

| Y-12 East Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average 09/30/2020 to 05/05/2021 | 7.90E-05 | 1.21E-05 | 5.14E-05 | 3.45E-04 | |
| Average background | 4.61E-05 | 7.08E-06 | 4.45E-05 | 3.84E-04 | |
| Net Activity (Avg. minus background) | 3.29E-05 | 5.06E-06 | 6.83E-06 | -3.92E-05 | |
| 40CFR Part 61 Limit, Appx. E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | 4.27E-03 | 7.12E-04 | 8.23E-04 | -2.80E-04 | 5.53E-03 |

### Oak Ridge National Laboratory

Two samplers were used at ORNL. Analyses for the air samples collected from air monitors at ORNL included three isotopes of uranium (U-234, U-235, U-238) and gamma spectrometry. The gamma spectrometry analysis results are not shown because only naturally occurring daughter products of radon were detected. No instances of elevated impacts were noted. The sum of fractions of less than one indicates that regulatory limits were not exceeded, as seen in tables 2.1.6 and 2.1.7.

**Table 2.1.6: ORNL B4007 Air Monitoring Average Results (pCi/m³)**

| ORNL B4007<br>Sampling Location | U-234 | U-235 | U-238 | Sum of Fractions |
|---|---|---|---|---|
| Average 07/01/2020 to 05/05/2021 | 5.08E-05 | 6.85E-06 | 4.37E-05 | |
| Average background | 4.61E-05 | 7.08E-06 | 4.45E-05 | |
| Net Activity (Avg. minus background) | 4.75E-06 | -2.36E-07 | -8.18E-07 | |
| 40CFR Part 61 Limit, Appendix E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | |
| Fraction of Limit (Net/Limit) | 6.16E-04 | -3.33E-05 | -9.86E-05 | 4.84E-04 |

**Table 2.1.7: ORNL Corehole 8 Air Monitoring Average Results (pCi/m³)**

| ORNL Corehole 8<br>Sampling Location | U-234 | U-235 | U-238 | Sum of Fractions |
|---|---|---|---|---|
| Average 07/01/2020 to 05/05/2021 | 5.10E-05 | 8.18E-06 | 4.09E-05 | |
| Average background | 4.61E-05 | 7.08E-06 | 4.45E-05 | |
| Net Activity (Avg. minus background) | 4.95E-06 | 1.10E-06 | -3.63E-06 | |
| 40CFR Part 61 Limit, Appendix E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | |
| Fraction of Limit (Net/Limit) | 6.43E-04 | 1.55E-04 | -4.37E-04 | 3.61E-04 |

### The Environmental Management Waste Management Facility

One sampler was located at EMWMF in Bear Creek Valley near Y-12. Analyses for the air samples collected from the air monitor at EMWMF included three isotopes of uranium (U-234, U-235, U-238) and Tc-99. No identified instances of elevated impacts were noted (Table 2.1.8). The sum of fractions of less than one indicates that regulatory limits were not exceeded.

**Table 2.1.8: EMWMF Air Monitoring Average Results (pCi/m³)**

| EMWMF Sampling Location | U-234 | U-235 | U-238 | Tc-99 | Sum of Fractions |
|---|---|---|---|---|---|
| Average 07/01/2020 to 05/05/2021 | 8.24E-05 | 2.02E-05 | 6.38E-05 | 2.83E-04 | |
| Average background | 4.61E-05 | 7.08E-06 | 4.45E-05 | 3.84E-04 | |
| Net Activity (Avg. minus background) | 3.63E-05 | 1.32E-05 | 1.93E-05 | -1.00E-04 | |
| 40CFR Part 61 Limit, Appx. E (Table 2) | 7.70E-03 | 7.10E-03 | 8.30E-03 | 1.40E-01 | |
| Fraction of Limit (Net/Limit) | 4.71E-03 | 1.85E-03 | 2.32E-03 | -7.18E-04 | 8.17E-03 |

### 2.1.8 Conclusions

The average concentrations, minus background, for all sites, were below the federal standards for each isotope measured.

This project's shorter composite intervals can result in the timelier observation of potential problems than other available sampling programs such as the DOE program which analyzes quarterly composite samples.

In past years, this TDEC DoR-OR independent monitoring project's Tc-99 analysis was useful in identifying a calculation error in DOE's ETTP Perimeter Sampling Program (with the error on the part of DOE's contracted laboratory) that reported results that were 10% of the actual calculated values. Results from this program continue to be used by DOE contractors for comparison purposes.

### 2.1.9 Recommendations

TDEC DoR-OR will review the current monitoring locations and consider sampling modifications according to DOE activities on the ORR.

### 2.1.10 References

40CFR Part 61 Limit, Appx. E (Table 2)

Title 40 of the Code of Federal Regulations Part 61 (40CFR61), National Emission Standards for Hazardous Air Pollutants (NESHAPS), Subpart H (National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities)

## 2.2 RADNET AIR

### 2.2.1 Background

In the past, air emissions from Department of Energy (DOE) activities on the Oak Ridge Reservation (ORR) were believed to have been a potential cause of illnesses affecting area residents. While these emissions have substantially decreased over the years, concerns have remained that air pollutants from current activities (e.g., production of radioisotopes and demolition of radioactive contaminated facilities) could pose a threat to public health, the surrounding environment, or both. Consequently, the Tennessee Department of Conservation (TDEC) Division of Remediation Oak Ridge office (DoR-OR) has implemented several air monitoring programs to assess the impact of ORR air emissions on the surrounding environment and the effectiveness of DOE controls and monitoring systems.

This project provides additional monitoring along with independent third-party analysis.

The RadNet Air Monitoring project on the ORR began in August of 1996 and provides radiochemical analysis of air particulate samples collected twice weekly from five air monitoring stations located near potential sources of radiological air emissions on the ORR. RadNet samples are collected by DoR-OR and analysis is performed at the EPA National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama.

### 2.2.2 Problem Statements

The three sites on the ORR, Oak Ridge National Laboratory (ORNL), the Y-12 National Security Complex (Y-12), and East Tennessee Technology Park (ETTP), can potentially release radioactive contaminants into the air from current operations, as well as from the deterioration of contaminated buildings at each site, and the decontamination and decommissioning (D&D) of these facilities.

### 2.2.3 Goals

- Protect the human health and the environment by assuring the public that the State of Tennessee independently evaluates gross beta activity in air on the ORR with the continuous monitoring of five RadNet Air monitoring stations, with up to 500 total samples analyzed yearly.

- Determine that levels of gross beta radioactivity are not above regulatory levels for a beta emitter with stringent criteria, and preferably below screening levels requiring additional analysis

- Compare gross beta levels from the RadNet Air monitors on the ORR to gross beta levels observed at a RadNet location not on the ORR that can be used as a background location

- Complement the TDEC DoR-OR Fugitive Radiological Air Emissions project by providing gross beta analysis (and other analyses if screening levels are exceeded) as well as provide additional air monitors for greater area coverage of the ORR, and provide more frequent analysis

### 2.2.4 Scope

The RadNet Air Monitoring project uses five high-volume air samplers to monitor air for radiological contamination. Two of the five air samplers are located at Y-12 (monitoring current operations and D&D); one is located near each end of the plant. One sampler is located at ETTP, off Blair Road (monitoring D&D). Two samplers are located at ORNL (monitoring current operations and D&D) ; one is in Bethel Valley, and one is in Melton Valley. Results from an additional RadNet air sampler operated by TDEC are used for background comparisons.

The five RadNet Air samplers on the ORR were sampled on Mondays and Thursdays except when skipped due to a holiday. Each of the samples were analyzed by EPA's NAREL for gross beta, which can mean the analysis of close to 500 samples from the ORR each year. Gamma analysis is performed on any samples with gross beta levels greater than 1 pCi/$m^3$ and on an annual composite of the year's samples at each station. Once every four years, the EPA laboratory performs uranium and plutonium isotopic analysis on an annual composite of the filters from each station.

### 2.2.5 Methods, Materials, Metrics

The locations of the five RadNet Air samplers are provided in Figure 2.2.1 and described in the scope of this project. EPA's analytical parameters and frequencies are listed in Table 2.2.1.

The RadNet Air samplers run continuously, collecting suspended particulates on synthetic fiber filters (10 centimeters in diameter) as air is drawn through the units by a pump at approximately 35 cubic feet per minute. TDEC DoR-OR collects the filters from each sampler, twice weekly, following EPA protocol (EPA, 1988; EPA, 2006). After collection, the filters are shipped to EPA's NAREL for analysis. Each year about 500 samples from the ORR are analyzed through this project. While gross beta analysis is used as a screening tool with further analysis triggered with levels over 1.0 pCi/ $m^3$, much lower levels can be seen with average minimum detectable concentrations of about 0.000353 pCi/ $m^3$ (for the ORR locations from 2010 through 2020).

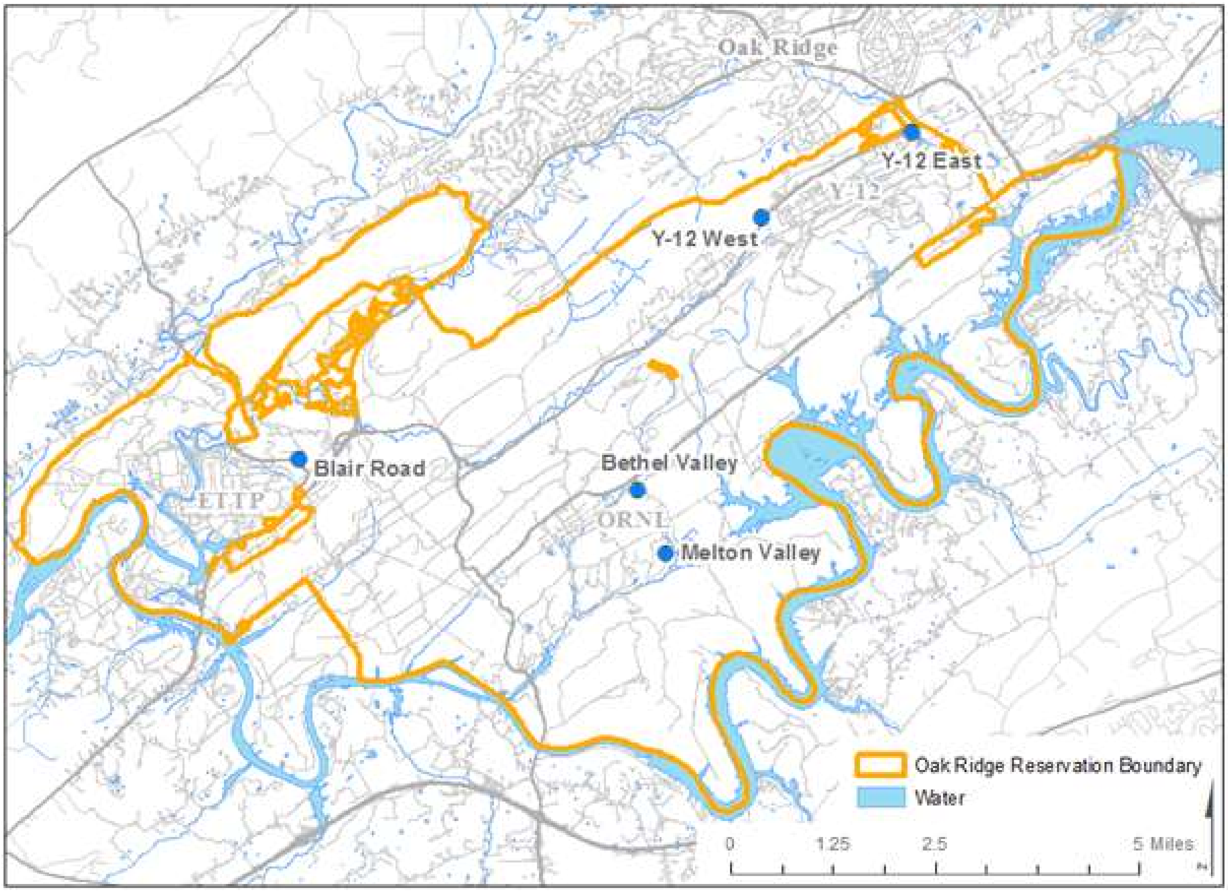



**Figure 2.2.1: Locations of RadNet Air Monitoring Stations on the ORR**

**Table 2.2.1: RadNet Air Monitoring Analyses and Frequencies**

| | **FREQUENCY** |
|---|---|
| Gross Beta | Each sample, twice weekly |
| Gamma Scan | As needed on samples showing greater than 1 pCi/$m^3$ of gross beta and annually on composite samples |
| Plutonium-238<br>Plutonium-239<br>Plutonium-240<br>Uranium-234<br>Uranium-235<br>Uranium-238 | Every four years on an annual composite from each station (started in 2014, previously done annually) |

The results of NAREL's analyses of the nationwide RadNet Air monitoring are available at NAREL's website in the Envirofacts RadNet searchable database.

Gross beta results from the RadNet Air Monitoring project are compared to background data from a RadNet Air monitor in Tennessee, as well as to the Clean Air Act (CAA) environmental limit for strontium-90, because it is a pure beta emitter with a conservative limit. The gross beta results provided by this project are useful both on their own, as the detection limits are low, and are useful as a screening tool because many gamma emitters also emit beta radiation.

### 2.2.6 Deviations from the Plan

At the time this report was written, data was available from July 2020 through June 14, 2021, so data for the second half of June was not included.

The ORR RadNet gross beta air sampling results were compared to those from the RadNet Air station located in Nashville instead of the Knoxville location as it was shut down for the duration of COVID and so was unavailable for comparison.

Also, the air sampler at the ETTP location became non-functional in May of 2021, so there were no samples collected after May 17, 2021. This occurred after the known radiological buildings at the ETTP site had been taken down. The co-located precipitation monitor was relocated to ORNL Bethel Valley, so there will be co-located air and precipitation samplers in both Bethel and Melton Valleys at ORNL.

Furthermore, the annual composite analysis for uranium and plutonium that is scheduled every four years was not done for 2017, instead it was completed for the 2018 composite samples. The most recent annual composite gamma analysis for RadNet air sampling on the ORR is also from 2018.

### 2.2.7 Results and Analysis

The results of NAREL's analyses of the nationwide RadNet Air sampling are available in the RadNet database on the Envirofacts website, via either a simple or a customized search. The results in this report are from samples collected from July 2020 through June 14, 2021, for the RadNet Air stations on the ORR, and the 2020 results as a whole are also discussed. Gross beta from the RadNet Air Monitoring project on the ORR was compared to background data from the RadNet Air monitor in Nashville, Tennessee, and to the CAA environmental limit for strontium-90, as it is a pure beta emitter with a conservative limit.

As seen in Figure 2.2.2, the results for the gross beta analysis of samples collected from July 2020 through June 2021 were similar for each of the five ORR RadNet monitoring stations and were similar to the results reported for the Nashville RadNet Air station (used as a background for comparison). The fluctuations observed in the results (depicted in Figure

2.2.2) were largely attributable to natural phenomena (wind and rain) that influence the amount of particulate suspended in the air and ultimately deposited on the filters. Some of the differences between the RadNet Air stations on the ORR and the background station in Nashville may be attributed to differences in weather and or collection schedules as well as the distance between the locations. The analytical gross beta result from the 2/1/21 Bethel Valley sample (0.0269 pCi/m$^3$) was noticeably higher than those from the other sampling locations at that time, with the next highest sample result for that date being nearly half the amount. While this elevated result could have been due to D&D activities on the ORNL site, the value was significantly lower than the level that automatically triggers additional analysis by EPA. The ORR gross beta results for the RadNet Air Monitoring project from July 2020 through June 14, 2021 were all well below 1.0 pCi/m$^3$, which is the screening level that triggers further analysis.

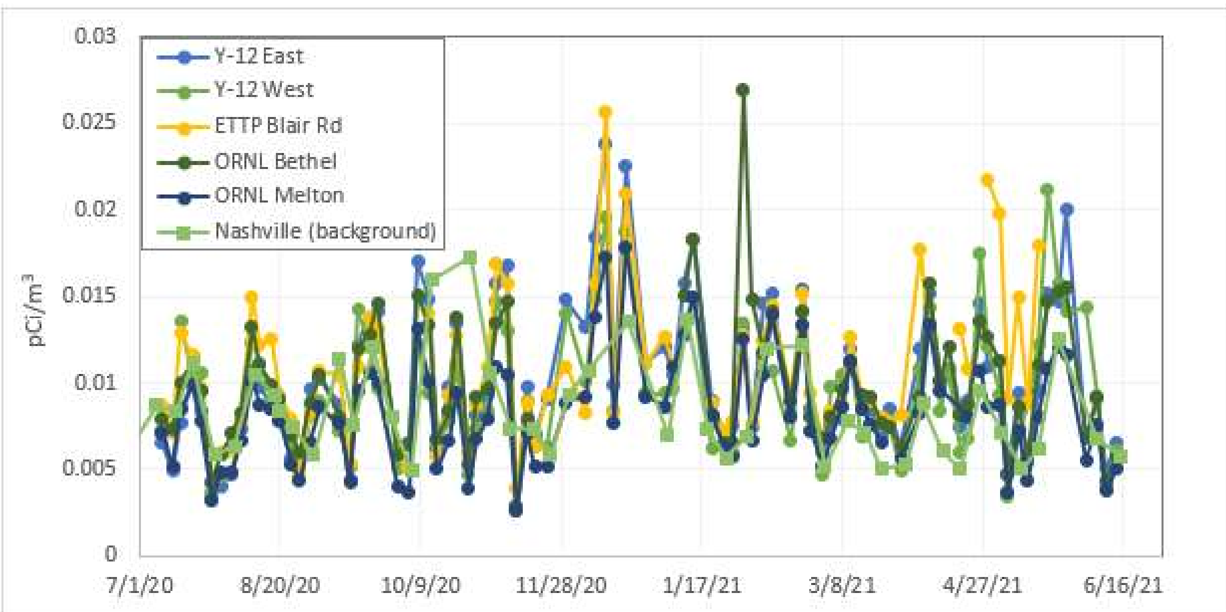



**Figure 2.2.2: RadNet Air Monitoring Project Gross Beta Results July 2020 - June 2021**

Note: This figure is intended to convey the correlation of the results for the various monitoring stations, not to depict individual results. Individual measurements are available online from EPA.

Figure 2.2.3 depicts the 2020 average gross beta results for each of the five stations in the ORR RadNet Air program, the average background concentration measured at the Nashville RadNet location, and the CAA environmental limit for strontium-90.

The CAA specifies that exposures to the public from radioactive materials released to the air from DOE facilities shall not cause members of the public to receive an effective dose equivalent greater than 10 mrem above background measurements in a year. For point-source emissions, compliance with this standard is generally determined with air dispersion models that predict the dose at offsite locations. The CAA also provides environmental concentrations for radionuclides equivalent to a dose of 10 mrem in a year (EPA 2010) to determine compliance.

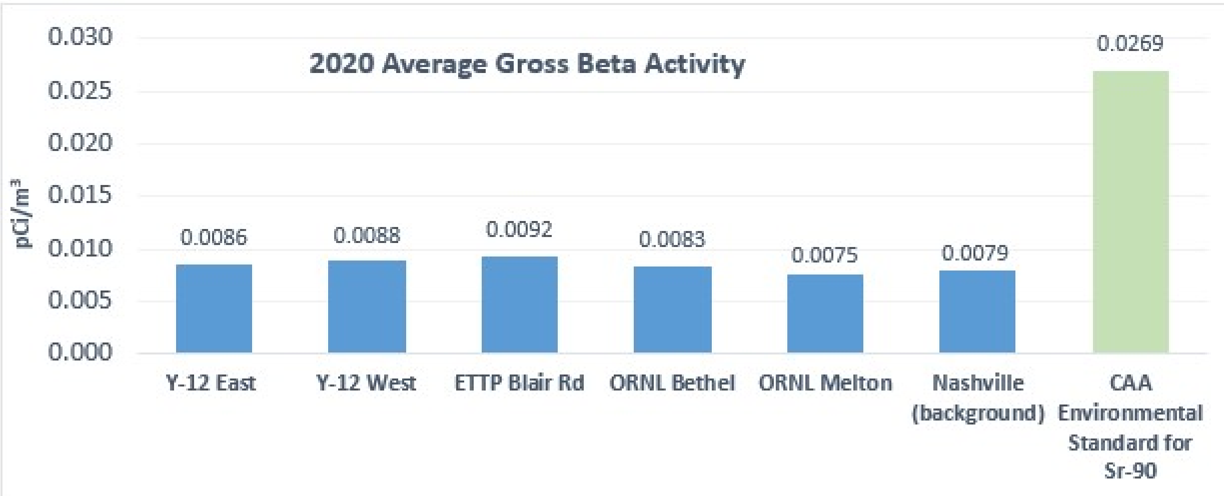



**Figure 2.2.3: 2020 RadNet Air Monitoring Program Average Gross Beta Results**

Note: For comparison, the 2019 average gross beta activity at the background location in Knoxville was 0.00842 pCi/m$^3$ and the average for the ORR RadNet stations was 0.0105 pCi/m$^3$. In 2020, the average for the ORR RadNet stations was 0.00852 pCi/m$^3$. Typical background values for gross beta range from 0.005 to 0.1 pCi/m$^3$ (ORISE, 1993). The standards provided by the Clean Air Act apply to the dose above background; therefore, the standard provided for reference in this figure has been adjusted to include the average of the background measurements taken from the RadNet station in Nashville for 2020 (CAA value for Sr-90 [0.019 pCi/m$^3$] + annual average gross beta at a background location=CAA environmental standard for Sr-90). The CAA's Environmental Limit for strontium-90 is used as a screening mechanism and is provided here for comparison. It is unlikely that this isotope contributes a major proportion of the gross beta activity reported for the samples**.**

To evaluate the RadNet data, the RadNet Air Monitoring project compares the average gross beta results reported for the project to the CAA limit for strontium-90, which has one of the most stringent standards of the beta-emitting radionuclides. The CAA standards apply to the dose above background, so the limit represented in Figure 2.2.3 was adjusted to include the average gross beta measurement taken at the RadNet station in Nashville, used as a background. It is important to note that strontium-90 is unlikely to be a large contributor to the total beta measurements reported here and is used only as a reference point to determine if further analysis is warranted.

While the 2020 results at all the RadNet Air stations are mostly comparable (results showed that sites responded in a similar pattern during each sampling period), the average gross beta results for the ORR RadNet Air Monitoring project in 2020 were lower at the ORNL Melton and ORNL Bethel locations. The station with the highest gross beta average for 2020 on the ORR was the ETTP Blair Road location. The average results from each of the ORR RadNet monitoring stations were below the strontium-90 limit (Figure 2.2.3).

None of the gross beta results reported for the RadNet Air Monitoring project on the ORR from July 2020 through June 2021 exceeded the screening level (1.0 pCi/m$^3$) which would have led to additional analysis by gamma spectrometry. The average minimum detectable concentration (MDC) was 0.000353 pCi/ m$^3$ for the ORR locations from 2010 through 2020. So, while 1 pCi/m$^3$ is the screening level which triggers further analysis by EPA, concentration levels of about 0.000353 pCi/m$^3$ and higher can be detected and compared. The actual MDC for each sample is sample specific, but usually isn't far from the average MDC.

The analysis for uranium and plutonium on annual composite samples is set to be performed every four years. The previous most recent composite results available were from 2013, which were presented in a prior report, with all values for each isotope below the limits established by the CAA. However, the composites for 2017 were not analyzed. Instead, the composite analysis of the 2018 samples for all the ORR RadNet samples were recently analyzed. The results of this analysis can be seen in Table 2.2.2 with units in pCi/m$^3$. This table lists individual values for each of the ORR sites as well as some values for comparison: average and maximum values for the ORR, a background location (Memphis, as that was the other data for Tennessee 2018 composite isotopic uranium and plutonium results), and the Clean Air Act standard limits. The Clean Air Act standard limits refer to the amount above background and are much higher than any of the Tennessee results. Of note, all plutonium-238 results were less than the associated MDCs, as were all but one of the plutonium-239 results, which was from the ETTP location. For isotopic uranium (U-234, U-235, U-238), the ORR average results were comparable to the background results (from Memphis). The maximum values, all from the Y-12 West location, were well below CAA limits.

**Table 2.2.2: 2018 Composite Results for Uranium and Plutonium in RadNet Air (aCi/m$^3$)**

| | Y-12 East | Y-12 West | ETTP Blair Rd | ORNL Bethel | ORNL Melton | ORR Average | ORR Maximum | Background (Memphis) | CAA standard (amount above background) |
|---|---|---|---|---|---|---|---|---|---|
| Plutonium-238 | 0.053 | 0.02 | 0.069 | 0.013 | -0.012 | 0.029 | 0.069 | 0.090 | 2100 |
| Plutonium-239 | 0.073 | 0.070 | 0.158 | 0.007 | 0.012 | 0.064 | 0.158 | 0.016 | 2000 |
| Uranium-234 | 16.7 | 35.1 | 11.6 | 6.0 | 3.2 | 14.5 | 35.1 | 15.2 | 7700 |
| Uranium-235 | 1.41 | 1.78 | 0.75 | 0.343 | 0.056 | 0.87 | 1.78 | 0.92 | 7100 |
| Uranium-238 | 7.21 | 25.2 | 10.85 | 4.81 | 2.81 | 10.2 | 25.2 | 15.0 | 8300 |

values in gray were less than the associated MDC

The 2018 composite gamma analysis for ORR RadNet sites are the most recent results available. While all Tennessee locations (Oak Ridge, Knoxville, Nashville, Memphis) had results for potassium-40 and sodium-22, and both Oak Ridge and Memphis had results for radium-228, three of the five Oak Ridge sites showed detectable amounts of cesium-137 (Cs-137), the two ORNL stations and the one at ETTP. The only Cs-137 results from Tennessee were from the ORR RadNet Air stations for the 2018 composite gamma analysis. The highest value seen was 9.3 aCi/$m^3$ at the ETTP location but is much lower than the compliance limit of 19,000 aCi/$m^3$ over background.

### 2.2.8 Conclusions

The gross beta results for each of the five RadNet Air monitoring stations exhibited similar trends and concentration levels for the period July 2020 through June 2021. All the data during this time period was well below the values which would warrant further analysis and does not indicate that activities on the ORR pose a significant impact on the environment or public health.

### 2.2.9 Recommendations

Continued ORR air monitoring for radiological contamination through this and other programs is recommended in order to ensure that air quality is protective of human health and the environment. This is especially important because of the demolition of contaminated buildings, movement of contaminated soils, operations, and other continued activities on the ORR. These activities all have the potential to impact air quality. In the event of a release either on or off the ORR, the RadNet Air Monitoring project would provide valuable information relating to the extent of radiological contamination in the air before, during, and after the event.

The RadNet Air Monitoring project is a valuable addition to other ORR air monitoring. First, annual sampling via the RadNet Air project collects and analyzes more samples than DOE air monitoring (twice weekly samples with approximately 100 samples analyzed yearly from each of the five locations on the ORR). Second, gross beta analysis is not only used as a screening tool with further analysis when levels exceed 1.0 pCi/ $m^3$, but it also can detect much lower levels with low sample specific MDCs, so it can be very effective at detecting elevated gross beta levels as well as variation. Third, gross beta analysis is an effective screening tool since few isotopes of interest are pure gamma or pure beta emitters. If there were a release on the ORR, it is likely there would also be some beta radiation emitted either directly or from daughter products. Consequently, this program would likely detect an increase in radiological levels in air and be able to better pinpoint the time of release due to analysis of twice weekly samples versus the quarterly compositing of weekly air filters done by DOE.

### 2.2.10 References

EPA (1988). Environmental Radiation Ambient Monitoring System (ERAMS) Manual. EPA 520/5-84-007, 008, 009.

EPA (2006). Andersen™ Flow Manager High Volume (FMHV) Air Particulate Sampler Operation Procedure. RadNet/SOP-3. Monitoring and Analytical Services Branch, National Air and Radiation Environmental Laboratory. Montgomery, Alabama.

EPA (2010). Clean Air Act. Code of Federal Regulations. Title 40: Protection of Environment. Part 61: National Emission Standards for Hazardous Air Pollutants. Appendix E, Table 2: Concentration Levels for Environmental Compliance.

EPA (2010). Clean Air Act. Code of Federal Regulations. Title 40: Protection of Environment. Part 61: National Emission Standards for Hazardous Air Pollutants. Subpart H: National Emissions Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities.

EPA (2021). NAREL RadNet Data links.

Envirofacts RadNet Searchable Database:

search https://enviro.epa.gov/enviro/erams_query_v2.simple_query

customized search https://www.epa.gov/enviro/radnet-customized-search

ORISE (1993). Environmental Air Sampling Handout from Applied Health Physics Course. Oak Ridge Institute for Science and Education (ORISE).

## 2.3 RadNet Precipitation

### 2.3.1 Background

Nationwide, the RadNet Precipitation Monitoring Project measures radioactive contaminants that are carried to the earth's surface by precipitation. On the Oak Ridge Reservation (ORR), the RadNet Precipitation Monitoring Project provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations. Samples are collected by the Tennessee Department of Environment and Conservation (TDEC) and gamma analysis is performed on monthly composite samples at EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama. Additional analysis may be conducted by NAREL if a radiological release is known or is indicated by monthly gamma analysis results. While there are no regulatory standards that apply directly to contaminants in precipitation, the data from this project provide an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by the TDEC or Department of Energy (DOE) air monitors.

The Environmental Protection Agency (EPA) has provided three RadNet precipitation monitors which are co-located with a RadNet air station at each of the three ORR sites. The first precipitation monitor is located at Oak Ridge National Laboratory (ORNL) in Melton Valley, in the vicinity of ORNL's High Flux Isotope Reactor and the Solid Waste Storage Area burial grounds. The second precipitation monitor is located off Blair Road to monitor contaminants from demolition activities at East Tennessee Technology Park (ETTP) and was moved to ORNL Bethel Valley starting in June 2021. The third station is located at the east end of the Y-12 National Security Complex (Y-12). In addition to monitoring Y-12, this station could potentially provide an indication of radioisotopes traveling toward the City of Oak Ridge from ORNL or Y-12. Analysis for gamma radionuclides is performed on the monthly composite samples for each of the three precipitation monitoring locations.

### 2.3.2 Problem Statements

The three sites on the ORR, ORNL, Y-12, and ETTP, have the potential to release radioactive contaminants into the air from previous and current operations as well as from the deterioration of contaminated buildings and the decontamination and decommissioning (D&D) of these facilities.

This project measures any radioactive constituents that are carried to the earth's surface by precipitation. The data provides an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by air monitors.

### 2.3.3 Goals

This project assesses the results from RadNet precipitation monitoring of gamma radionuclides to assure the public that human health and the environment are being protected.

The results from the project can be used to:

- Identify anomalies in gamma concentrations in precipitation on the ORR
- Assess the significance of precipitation in contaminant pathways
- Evaluate contamination control measures during D&D or remediation activities on the ORR

- Compare precipitation concentrations from the ORR with other locations in the nationwide EPA RadNet Program

- Determine levels of local contamination in the event of a nuclear incident

### 2.3.4 Scope

Three precipitation samplers are used to monitor the precipitation for potential radiological contamination. Each sampler is co-located at a RadNet air station at each of the three ORR sites. One sampler is located at the east end of the Y-12 plant. One unit is located at ETTP, off Blair Road. The third sampler is located at ORNL in Melton Valley. These locations are shown in Figure 2.3.1. The three precipitation samplers co-located with the RadNet Air samplers on the ORR were sampled Mondays and Thursdays, except when skipped due to a holiday. The precipitation samples are composited monthly at the EPA laboratory and analyzed for gamma radionuclides. Additional analysis on individual samples would likely be conducted in the event of elevated findings or for a nuclear release.

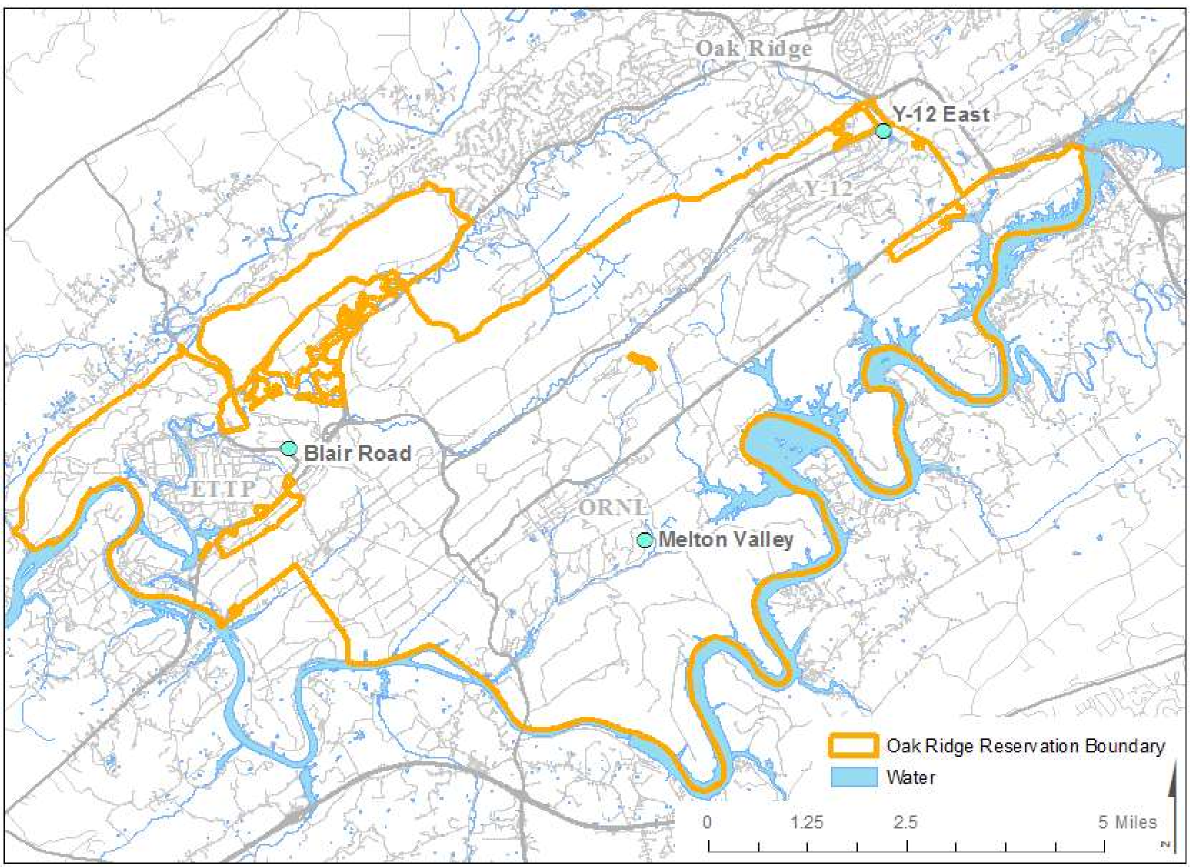



**Figure 2.3.1: Locations of the RadNet Precipitation samplers on the ORR**

### 2.3.5 Methods, Materials, Metrics

The three precipitation samplers provided by EPA's RadNet Air Monitoring program (locations shown in Figure 2.3.1) were used to collect samples for the RadNet Precipitation Monitoring Project. Each sampler drains precipitation that falls on a 0.5 square meter fiberglass collector into a five-gallon collection bucket. Each sample is measured, then collected from the bucket (into a four-liter container) and sent to EPA when a minimum of two liters of precipitation has accumulated, or less when it is the final sample of the month. Each sample is processed as specified by EPA (EPA, 1988; EPA, 2017) and then shipped to NAREL in Montgomery, Alabama, for analysis. NAREL composites the samples collected during a month for each station and analyzes each composite for gamma radionuclides. The gamma analysis functions as a screening tool because few isotopes of interest are pure beta or pure gamma emitters, so if there were a release on the ORR, it is likely there would be some gamma radiation emitted either directly or from daughter products. Additional analysis may be conducted if there is a known radiological release or is indicated by monthly gamma analysis results.

No regulatory limits for radiological contaminants in precipitation exist, so the results of the gamma analyses were compared to drinking water limits established by the EPA as conservative reference values. EPA's Radionuclides Rule for drinking water allows gross alpha levels of up to 15 picocuries per liter (pCi/L), while beta and gamma emitters are limited to 4 millirem (mrem) per year and are radionuclide specific. A combined value for radium-226 and radium-228 of up to 5 pCi/L is also allowed. Table 2.3.1 shows the maximum contaminant levels (MCLs) of beta and gamma emitters that EPA uses as drinking water limits for select isotopes. Not all gamma producing isotopes have EPA drinking water limits. Results from the ORR-located RadNet Precipitation Monitoring stations can also be compared to other sites in the EPA RadNet program. However, while the stations located on the ORR are in areas near nuclear sources, most of the other stations in the RadNet Precipitation Monitoring Project are located near major population centers, with no major sources of radiological contaminants nearby.

This project report was prepared to assist with the State of Tennessee's commitments under the Environmental Surveillance Oversight Agreement (ESOA) for the ORR. In accordance with those agreements, a portion of the time spent on this project will be in reviewing the DOE Environmental Monitoring Plan (EMP) and Annual Site Environmental Report (ASER) for the ORR and/or applicable FFA remedy documents. This project may evaluate data from various sources to include, but not limited to, data uploaded to the Oak Ridge Environmental Information System (OREIS), data provided to or collected by other State regulatory agencies, split sampling with DOE parties, or independent sampling in accordance with accepted standard procedures. Information analyzed by the TDEC Division of Remediation, Oak Ridge Office (DoR-OR) will be used to make recommendations to existing DOE environmental surveillance programs.

**Table 2.3.1: EPA Drinking Water Limits (MCLs) for Select Isotopes**

| Isotope | EPA limit (pCi/L) |
|---|---|
| Barium-140 (Ba-140) | 90 |
| Beryllium-7 (Be-7) | 6,000 |
| Cobalt-60 (Co-60) | 100 |
| Cesium-134 (Cs-134) | 80 |
| Cesium-137 (Cs-137) | 200 |
| Tritium (H-3) | 20,000 |
| Iodine-131 (I-131) | 3 |

### 2.3.6 Deviations from the Plan

The results in this report would normally cover July 2020 through June 2021 but were only available through November 2020 because of delayed analysis due to COVID. Hence, only the January 2020 through November 2020 results are discussed.

Also, in June 2021, the precipitation sampler that was co-located at the ETTP location was moved to the ORNL Bethel Valley location (co-sampling with the RadNet air monitor at that location). Accordingly, as the new location June 2021 results were not yet available, only the data pertaining to the original ETTP location are discussed in this report.

### 2.3.7 Results and Analysis

The results of NAREL's analyses of the nationwide RadNet Precipitation sampling are available in the RadNet database on the Envirofacts website (EPA, 2021), via either a simple or a customized search. The gamma isotopes identified from January 2020 through November 2020 sampling results from the ORR include beryllium-7, cesium-137, cobalt-60, potassium-40, and radium-228. For all isotopes except beryllium-7 and potassium-40, the reported results for each isotope were all less than the minimum detectable concentration (MDC). As stated in the RadNet user guide, the MDCs reflect "*the ability of the analytical process to detect the analyte for a given sample. The MDC is the activity concentration for which the analytical process detects the radioactive material in a given sample that provides a 95% chance that the radioactive material will be detected.*" The ORR beryllium-7, potassium-40, and radium-228 results are discussed below.

The average result for beryllium-7 for the three ORR samplers from January 2020 through November 2020 was 74.7 pCi/L, compared to an average MDC of 43 pCi/L. The national average for beryllium-7 for the same time period was 50.1 pCi/L. The highest beryllium-7 result for the ORR stations during this time period was 120 pCi/L. When compared to the conservative EPA drinking water limit for beryllium-7 of 6,000 pCi/L, the values seen in the monthly composite precipitation samples on the ORR are relatively small.

While most of the potassium-40 results were below detection limits from January 2020 through November 2020, one of the thirty-three samples did show detectable levels, at the ORNL Melton Valley location. This potassium-40 result was greater than, but just over, the sample specific detection limit. Potassium-40 is a naturally occurring radionuclide and does not have a drinking water limit.

None of the ORR RadNet Precipitation results from January 2020 through November 2020 showed radium-228 levels greater than sample specific detection limits. A combined value for radium-226 and radium-228 of up to 5 pCi/L is also allowed by EPA's Radionuclides Rule for drinking water. Radium is naturally occurring and found in the earth at trace levels as well as in the air.

### 2.3.8 Conclusions

Overall, the highest values seen in the composited monthly precipitation samples for each of the three ORR stations were all below the MCLs set by the EPA for drinking water. While there are no regulatory limits for radionuclides in precipitation, the comparison to EPA's drinking water limits were used as conservative reference values. All results for cesium-137 and cobalt-60 for this time period were less than the MDCs**.** The data from January 2020 through November 2020 were below detection limits or below the regulatory limits used for drinking water and did not indicate a significant impact on the environment or public health from ORR emissions.

### 2.3.9 Recommendations

Continued monitoring of the ORR precipitation for radiological contamination via the ORR RadNet Precipitation project is recommended in order to ensure that contamination in precipitation seen on the ORR does not present risk to human health and the environment. This is especially important as the demolition of older buildings continues at the ORR sites. Current operations also have the potential to impact precipitation contaminant levels. In the event of an emergency either on or off the ORR, this program would also provide valuable data relating to the extent of radiological contamination in the air and precipitation before, during, and after an event.

### 2.3.10 References

EPA (1988). Environmental Radiation Ambient Monitoring System (ERAMS) Manual. EPA 520/5-84-007, 008, 009.

EPA (2000). Radionuclides in Drinking Water. Radionuclide Rule. http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/

EPA (2001). Radionuclides Rule: A Quick Reference Guide. EPA 816-F-01-003. http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/

EPA (2017). NAREL Standard Operating Procedure for Collecting RadNet Precipitation Samples. SC/SOP-2. National Analytical Radiation Environmental Laboratory, Office of Radiation and Indoor Air. Montgomery, Alabama.

EPA (2015). Derived Concentrations of Beta and Photon Emitters in Drinking Water. https://www.epa.gov/sites/production/files/2015-09/documents/guide_radionuclides_table-betaphotonemitters.pdf

EPA (2021). Environmental Protection Agency- NAREL RadNet Data links.

Envirofacts RadNet Searchable Database:

search https://enviro.epa.gov/enviro/erams_query_v2.simple_query

customized search https://www.epa.gov/enviro/radnet-customized-search

user guide https://www.epa.gov/enviro/radnet-search-user-guide

# 3.0 BIOLOGICAL MONITORING

## 3.1 BENTHIC COMMUNITY HEALTH

### 3.1.1 Background

The Benthic Macroinvertebrate Monitoring Project monitors the current condition and changing conditions of stream-bottom communities in streams on the Oak Ridge Reservation (ORR). These streams have been negatively impacted by historical Manhattan Project activities as well as current operational activities at the three facilities on the reservation: East Tennessee Technology Park (ETTP), Oak Ridge National Laboratory (ORNL), and the Y-12 National Security Complex (Y-12). The purpose of the Benthic Community Health Project is to document the current condition of these stream communities and to note the changes of these conditions as remedial activities continue under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Stream-bottom communities (aquatic insects and other macroinvertebrate species) serve as indicators of the health of aquatic systems. The majority of the lives of these organisms are spent in water. They are continually exposed to conditions caused by direct or indirect discharges to these waters. Un-impacted reference streams are used to define what a healthy community would look like. That determination is then compared to those assessments of impacted sites in streams on the ORR to help determine the extent of the suspected impacts.

East Fork Poplar Creek (EFPC), Bear Creek, Mitchell Branch, and White Oak Creek (WOC) are the four main watersheds studied at the three facilities on the ORR. EFPC and Bear Creek serve as the watersheds on the Y-12 site. Mitchell Branch serves as the main watershed on the ETTP site. WOC is the primary watershed on the ORNL site. Both onsite and offsite streams serve as reference sites for these watersheds.

ORNL staff also conduct benthic macroinvertebrate monitoring on many of the same streams as TDEC Division of Remediation, Oak Ridge (TDEC DoR-OR). However, a number of the specific sites monitored differ between the two organizations. Even where the specific sites are the same, TDEC DoR-OR's sampling serves as an independent check on ORNL's monitoring results. Determining impacts on stream bottom communities is a difficult task and results and interpretations may vary among different sampling and analysis personnel, which may cause some results to be slightly different. An independent evaluation helps to produce a clearer picture of actual conditions in ORR streams.

All work on this project follows the requirements of TDEC Division of Remediation Oak Ridge *Office Health and Safety Plan* (TDEC 2019).

### 3.1.2 Problem Statements

Benthic macroinvertebrate communities at the majority of sites in the four main watersheds in this study do not compare well with healthy communities from un-impacted reference streams. Intolerant species (organisms that do not survive well in polluted areas) are found in significantly fewer instances and smaller quantities at a number of ORR sampling sites. Similarly, tolerant species (organisms that survive and can tolerate polluted areas) are found in significantly more instances and higher quantities in a number of ORR sampling sites. These findings indicate stream impairment due to anthropogenic activity. Many of the impacts affecting these streams result from both historical Manhattan Project activities as well as current operational activities on the ORR. The majority of these impacts are due to typical industrial contaminants (e.g., residual chlorine and other chemical releases [both chronic and acute], and organic loading from point and non-point discharges) and are not related to the radiological contamination of the ORR sampling sites. In areas where stream sections have been channelized, problems may be due to a lack of appropriate substrates for the establishment of healthy stream-bottom communities.

Variability in the data may result from a multitude of factors. Part of this variability is due to the natural year-to-year fluctuations in benthic communities (flow rates, heat waves, storm events, etc.). Another part of this variability is due to variation among samplers. Because of these sources of variability, data recorded from benthic community monitoring benefits from long term sampling and sampling with different experienced personnel. Caution should be exercised in the interpretation of these data.

In 2020, routine benthic macroinvertebrate sampling was disrupted by the COVID-19 pandemic and policies that aimed to control its virulent spread. These policies prevented TDEC DoR-OR staff from collecting their usual Spring sample. Instead, samples were collected in early Fall. Metrics for calculating the Tennessee Macroinvertebrate Index (TMI) were adjusted to account for the time of year using the *TDEC Division of Water Quality Standard Operating Procedure for Macroinvertebrate Stream Surveys* – Protocol F and Protocol K (TDEC DWQ SOP 2017).

### 3.1.3 Goals

The goals of the Benthic Macroinvertebrate Monitoring Project are varied:

- Primary among these goals was to monitor the current condition and health of benthic communities at stream sites on the ORR.
- A second goal was to provide data for comparison with other ongoing DOE studies of benthic communities. There is normal year-to-year variation in benthic communities, as well as sampling technique. A comparison of data from different sources could clarify the current conditions at the ORR sites.
- A third goal was to better understand the causes of impacts in benthic communities on the ORR.
- A fourth goal of benthic macroinvertebrate monitoring was to provide recommendations on potential changes that may be made to help improve the current health of streams on the ORR and off the ORR where primary impacts are due to the Oak Ridge facilities.

### 3.1.4 Scope

The physical boundaries of the Benthic Macroinvertebrate Monitoring Project included streams of the major watersheds on the three facilities of the ORR. At ORNL, these streams included WOC (from its headwaters to near its confluence with White Oak Lake) and Melton Branch. At Y-12, these streams included EFPC from its headwaters to stream-kilometer 6.3 and, Bear Creek from the headwaters to its confluence with EFPC. At ETTP, Mitchell Branch was surveyed from its headwaters to near its confluence with Poplar Creek. Also included in these physical boundaries are offsite reference sites for the study which include Hinds Creek and Clear Creek.

In 2020, TDEC DoR-OR conducted benthic macroinvertebrate monitoring surveys of the watersheds, streams, and stations listed in **Error! Reference source not found.**. Maps for all 2020 sampling locations are included in Figure 3.1.1 and Figure 3.1.2. Sampling included two 1 $m^2$ composited samples for each study site.

All sampling in 2020 occurred between the beginning of September and October. Specific sampling dates were dependent on availability of staff to perform the sampling, vehicles, and recent weather conditions (i.e., sampling is best completed under normal, not high-water flows). At sites where samples were taken both by TDEC DoR-OR and ORNL, care was taken to plan for a two- to three-week sampling time difference to allow for recovery of the benthic community.

Sample processing occurred in the TDEC DoR-OR laboratory and was performed by experienced benthic macroinvertebrate taxonomists. Processing took place between May and September 2021.

**Table 3.1.1: 2020 Benthic Macroinvertebrate Monitoring Locations**

| 2020 Benthic Macroinvertebrate Monitoring Locations | | | |
|---|---|---|---|
| Facility | Watershed | Station | Reference Station |
| ETTP | Mitchell Branch | MIK 0.45 | MIK 1.43 |
| ORNL | White Oak Creek | WCK 3.9 | HCK 20.6 |
| | | MEK 0.3 | |
| Y-12 | East Fork Poplar Creek | EFK 6.3 | CCK 1.6 |
| | | EFK 23.4 | |
| | | EFK 25.1 | |
| | Bear Creek | BCK 3.3 | |
| | | BCK 12.3 | |

MIK = Mitchell Branch Kilometer, WCK = White Oak Creek Kilometer, MEK = Melton Branch Kilometer, HCK = Hinds Creek Kilometer, EFK = East Fork Poplar Creek Kilometer, CCK = Clear Creek Kilometer, BCK = Bear Creek Kilometer

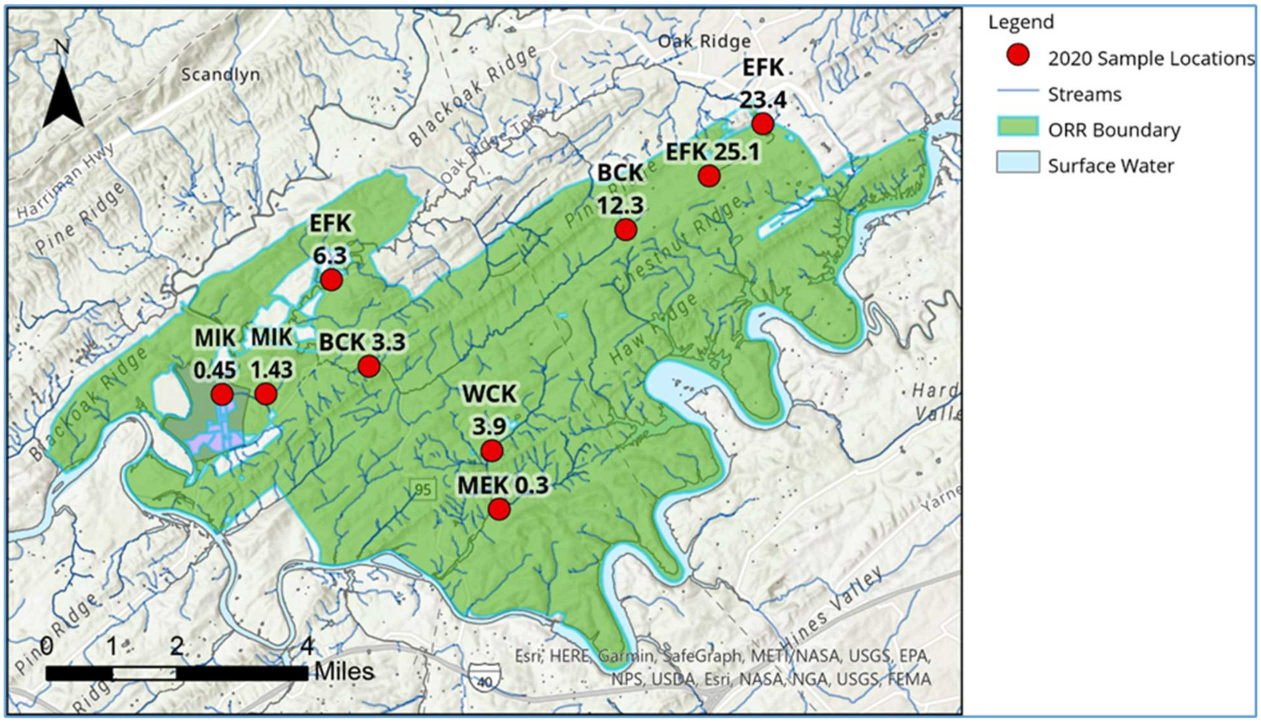



**Figure 3.1.1: All Benthic Macroinvertebrate Sampling Locations (excluding reference location CCK 1.6 and HCK 20.6)**

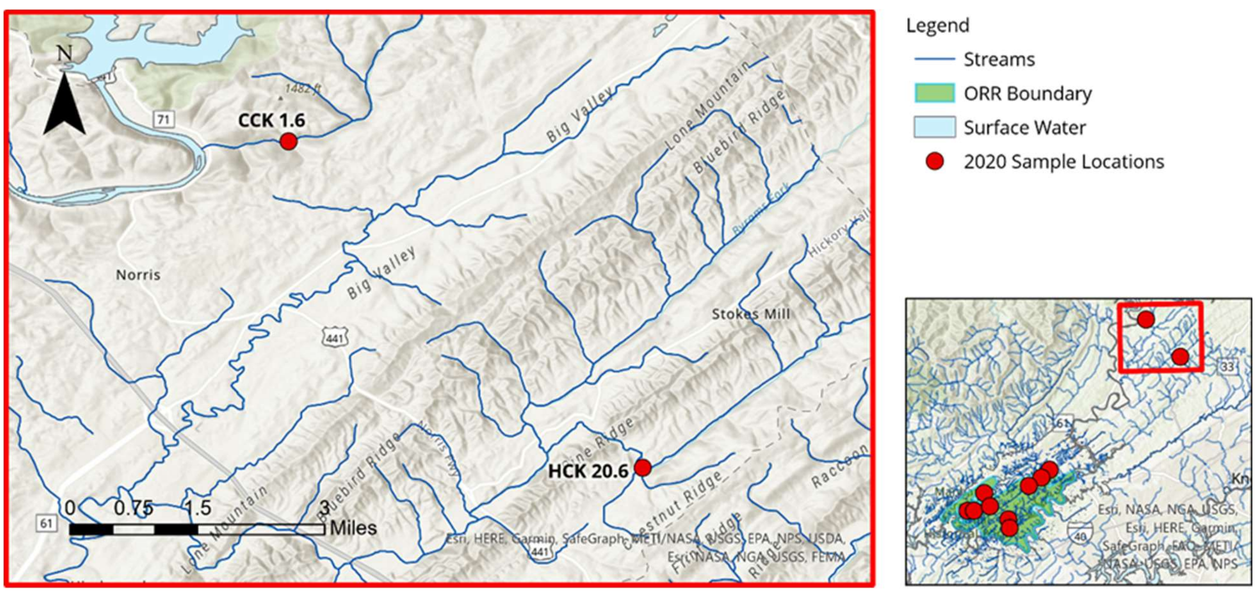



**Figure 3.1.2: Benthic Macroinvertebrate Sampling Location CCK 1.6**

### 3.1.5 Methods, Materials, Metrics

**Sample Collection:**

Sampling for this project required two people at a minimum. One person set a one-square-meter kick net with a 500-micron mesh across a predetermined riffle. The other person, using a heavy-duty garden rake, disturbed approximately 1 $m^2$ area of the stream substrate directly upstream of that net. The organisms, sediment, and detritus flowed into the net. The net was then carefully lifted out of the water and carried horizontally to the streambank. The bottom of the net was positioned in a 500-micron sieve bucket. The net was thoroughly rinsed into the sieve bucket. This process was repeated using a second riffle. The two kicks were then composited, placed in a plastic container, and preserved with 95% ethanol.

**Sample Processing:**

Processing of benthic samples consisted of two major steps. The first step was sample sorting, where benthic organisms were removed from the detrital material collected along with the organisms.

The second step in processing was sample identification of the organisms collected. The larger macroinvertebrates were identified by an experienced taxonomist using a binocular dissecting scope and the appropriate organism identification keys, where needed. The smaller macroinvertebrates, which include the *Chironomidae* (non-biting midges) and the smaller *Oligochaeta* (worms), were mounted on slides and identified by an experienced taxonomist using a binocular compound light microscope and the appropriate keys.

The majority of the samples were preserved and brought to the TDEC DoR-OR laboratory for processing. In the case of WOC and Melton Branch, where elevated levels of radionuclides occur, sorting was performed in the field so that contaminated sediments could be returned to their source and not brought into the laboratory.

Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC DWQ SOP 2017) requires identification of taxa to only the genus-level. Calculations of all metrics for this study were determined using the genus-level identifications.

**Data Analysis:**

Once sample identifications were complete, the identifications for each sample were totaled for each genus and entered into an Excel spreadsheet. The data were then used to calculate the various metrics used in the analysis. The metrics were totaled for each sample and comparisons of impacted sites to reference sites were made. A description of each metric and the expected responses to environmental stressors is listed in Table 3.1.2.

**Table 3.1.2: Descriptions of Metrics and Expected Responses to Stressors**

| Description of Metrics and Expected Responses to stressors | | | |
|---|---|---|---|
| Category | Metric | Description | Response to stress |
| Richness Metrics | Taxa Richness | Measures overall diversity of the macroinvertebrate assemblage | Number Decreases |
| | EPT Richness | Number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera | Number Decreases |
| | Intolerant Taxa | Number of taxa in sample that display a tolerance rating of < 3.0 | Number Decreases |
| Composition Metrics | % EPT - Cheum | % of ETP abundance excluding Cheumatopsyche taxa | % Decreases |
| | % OC | % of Oligochaetes and Chironomids present in sample | % Increases |
| Tolerance Metrics | NCBI | North Carolina Biotic Index which incorporates richness and abundance with a numerical rating of tolerance | Number Increases |
| | % Total Nutrient Tolerance (%TNUTOL) | % of organism present in sample that are considered tolerant of nutrients | % Increases |
| Habitat Metric | % Clingers | % of macroinvertebrates present in sample w/ fixed retreats or attach themselves to substrates | % Decreases |

### 3.1.6 Deviations from the Plan

In March 2020, the TDEC Senior Leadership Team enacted state-wide policies aimed at limiting the virulent spread of COVID-19. One policy halted all field operations and prevented TDEC DoR-OR staff from conducting their routine benthic macroinvertebrate sampling events. In the past, sample collection has always taken place in the Spring, between May and early-June.

In May 2020, The TDEC Senior Leadership Team lifted many of the policies that restricted field operations. Benthic macroinvertebrate samples were collected between September and early-October. TDEC DoR-OR staff adhered to guidance from the TDEC DWQ SOP 2017 for Fall sampling. Metrics were adjusted using the Fall 2020 data to provide data sets that are comparable to historical Spring sampling described in Protocol F and Protocol K.

Some of the streams monitored on the ORR did not meet the conditions necessary for comparison of results to bioregion biocriteria of Tennessee. The primary condition not met was that certain streams in the study were headwater streams (< 2 square miles of drainage area). An alternative reference stream method was used to evaluate the study's results.

In order to generate a table of values for comparison of reference stations to potentially impacted stream stations, eight metrics were first calculated for all of the reference stations (CCK 1.6, GHK 2.9, HCK 20.6, and MIK 1.43). Based on the average value of each metric and using the calculations provided in Section I.I, Protocol K: Page 5 of the TDEC DWQ SOP 2017, ranges of values for ratings of 6, 4, 2, and 0 for each metric were further determined. The adjusted metric data for the 2020 data is found in Table 3.1.3.

**Table 3.1.3: Alternative Reference Stream Metrics**

| Alternate Reference Stream Metrics | | | | |
|---|---|---|---|---|
| Metric | 6 | 4 | 2 | 0 |
| Taxa Richness | ≥ 27 | 16 - 26 | 12 - 15 | ≤ 11 |
| EPT Richness | ≥ 11 | 8 - 10 | 6 - 7 | ≤ 5 |
| % EPT - Cheum | ≥ 18.60 | 13.95 - 18.59 | 13.94 - 10.46 | ≤ 10.45 |
| % OC | ≤ 3.70 | 3.71 - 4.63 | 4.64 - 5.79 | ≥ 5.80 |
| NCBI | ≤ 5.90 | 5.91 - 7.38 | 7.39 - 9.22 | ≥ 9.23 |
| % Clingers | ≥48.80 | 48.79 - 36.60 | 36.59 - 27.45 | ≤ 27.45 |
| % Tolerant Taxa | ≤ 43.02 | 43.03 - 53.78 | 53.79 - 67.22 | ≥ 67.23 |
| Intolerant Taxa | ≥ 8 | 7 - 6 | 5 - 4 | ≤ 3 |
| Ave. Reference: CCK 1.6, HCK 20.6, MIK 1.43<br>Season: July - December<br>Genus Level Identification | | | Method: SQKICK<br>TDEC DWQ SOP 2017<br>Section I.I, Protocol K, P.5 | |

### 3.1.7 Results and Analysis

**East Fork Poplar Creek**

Tennessee Macroinvertebrate Index (TMI) scores (alternative reference stream method), and biological condition ratings are presented in Table 3.1.4 for the EFPC watershed. The stream numbers represent distances in kilometers that decrease from headwaters (EFK 25.1) towards the mouth downstream (EFK 0.0). The reference stream for the EFPC watershed is Clear Creek (CCK 1.6).

Impacts occur from the headwaters of EFPC to a considerable distance downstream in the watershed. The headwaters of the stream originate from tributaries that flow through stormwater conduits in the main industrialized portion of Y-12. Near its origin, EFPC receives inputs of contaminants such as mercury, uranium, volatile organic compounds (VOCs) and other metals and organics. Once leaving the Y-12 boundary, EFPC receives further contaminant loading from urban and suburban runoff as well as a sewage treatment plant discharge. Downstream, it flows through urbanized and suburbanized sections of Oak Ridge before flowing through less developed areas prior to its confluence with Poplar Creek. Only near its mouth does EFPC flow through relatively undisturbed terrain.

**Table 3.1.4: EFPC TMI Scores and Biological Condition Rating**

| Total Metric Index Scores | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | EFK 6.3 | | EFK 23.4 | | EFK 25.1 | | CCK 1.6 | |
| | TMI | RATING | TMI | RATING | TMI | RATING | TMI | RATING |
| 2010 | 28 | **B** | 20 | **C** | 14 | **C** | 44 | **A** |
| 2011 | 30 | **B** | 20 | **C** | 10 | **C** | 44 | **A** |
| 2012 | 30 | **B** | 26 | **B** | 20 | **C** | 46 | **A** |
| 2013 | 28 | **B** | 20 | **C** | 26 | **B** | 42 | **A** |
| 2014 | 28 | **B** | 28 | **B** | 22 | **B** | 48 | **A** |
| 2015 | 26 | **B** | 20 | **C** | 14 | **C** | 48 | **A** |
| 2016 | 28 | **B** | 24 | **B** | 20 | **C** | 48 | **A** |
| 2017 | 28 | **B** | 26 | **B** | 18 | **C** | 48 | **A** |
| 2018 | 28 | **B** | 26 | **B** | 16 | **C** | - | **-** |
| 2019 | 28 | **B** | 26 | **B** | 26 | **B** | 44 | **A** |
| 2020 | 32 | **A** | 30 | **B** | 16 | **C** | 42 | **A** |
| Key: | A = Supporting / Non Impaired (TN Macro. Index Scores >= 32)<br>B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31)<br>C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20)<br>D = Non Supporting / Severely Impaired (TMI Scores < 10) | | | | | | | |

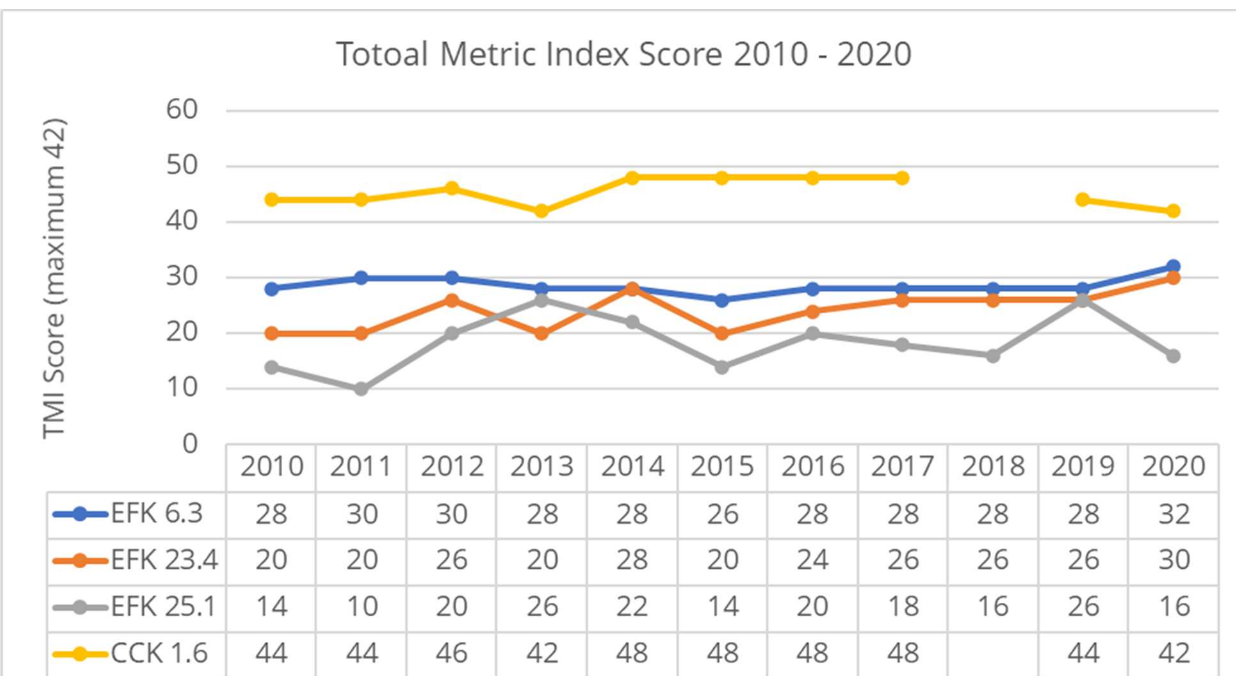



**Figure 3.1.3: Total Metric Index Scores in East for Poplar Creek and Clear Creek Reference Station from 2010 – 2020**

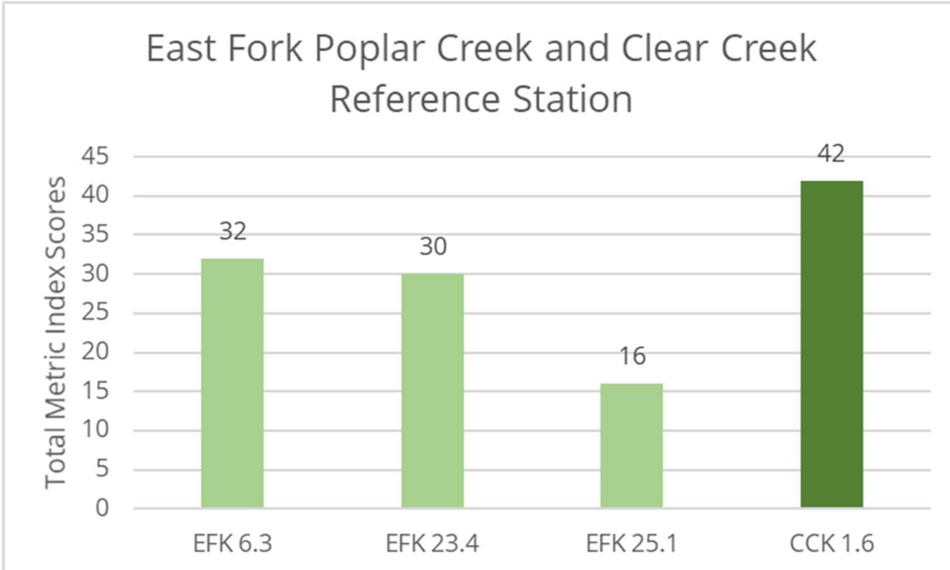



**Figure 3.1.4: 2020 Total Metric Index Scores in EFPC and Clear Creek Reference Station**

EFK 25.1 has historically been one of the lowest-scoring benthic macroinvertebrate monitoring sites on the ORR. In the past 10 years, EFK 25.1 has scored, on average, 27 points lower per year than its corresponding reference station (Figure 3.1.3). There are many factors that may be contributing to this. Channelization at the headwaters of EFPC reduces the amount of viable habitat. Water temperatures are typically higher in this creek section year-round. Additionally, this location receives the highest concentration of contaminants from Y-12 facilities. In the past, flow was supplemented from the Clinch River in order to dilute the contaminants, but this practice was discontinued in 2014.

TDEC DoR-OR noted that EFK 25.1 did not compare well with reference station CCK 1.6 in 2020 (Figure 3.1.4). This was expected and does not represent a drastic change from historical trends.

EFK 6.8 and EFK 23.4 have remained relatively stable over the past decade, with only small variations year-to-year which can be attributed to a multitude of factors (including TDEC DoR-OR staff changes, climate fluctuations, or heavy rain events in the days prior to collection) (Figure 3.1.3). Both EFK 6.3 and EFK 23.4 had a lower TMI score in 2020 than reference station CCK 1.6 (Figure 3.1.4). This was expected, however, both locations showed some improvement in 2020.

The biological condition rating for EFK 6.3 was “Supporting/Non Impaired” in 2020. There was a large number of intolerant and clinger taxa and a low number of oligochaete and chironomid taxa found in the sample (Table 3.1.5).

**Table 3.1.5: Benthic Macroinvertebrate Metric Results for EFPC and Clear Creek Reference Station**

| Benthic Macroinvertebrate Metrics Results | | | | |
|---|---|---|---|---|
| | EFK 6.3 | EFK 23.4 | EFK 25.1 | CCK 1.6 |
| Taxa Richness | 16 | 15 | 20 | 37 |
| EPT Richness | 7 | 3 | 3 | 17 |
| %EPT-CHEUM | 43.40% | 16.75% | 3.87% | 16.59% |
| %OC | 0.00% | 1.80% | 5.48% | 5.24% |
| NCIB | 4.96 | 4.22 | 6.43 | 4.92 |
| %Clingers | 93.06% | 72.94% | 75.16% | 64.19% |
| Tolerant Taxa | 48.26% | 18.56% | 71.61% | 33.84% |
| Intolerant Taxa | 4 | 2 | 2 | 14 |

**Bear Creek**

Bear Creek is a small to moderate-sized stream whose headwaters begin partly in the west end of the industrialized complex at Y-12. Historically, Bear Creek has received pollution from industrial activities, as well as waste disposal activities at Y-12. Former waste sites, such as the S3 ponds (at its headwaters), continue to negatively influence the water quality of the stream. Downstream from its source, Bear Creek continues to be impacted by inputs from various former and current waste sites. Bear Creek is also a stream where shallow groundwater and surface waters mingle freely throughout its length to its confluence with EFPC. CCK 1.6 is its corresponding reference station in 2020.

**Table 3.1.6: Bear Creek TMI Scores and Biological Condition Rating**

| Total Metric Index Scores | | | | | | |
|---|---|---|---|---|---|---|
| | BCK 3.3 | | BCK 12.3 | | CCK 1.6 | |
| | TMI | RATING | TMI | RATING | TMI | RATING |
| 2010 | - | - | 30 | **B** | 44 | **A** |
| 2011 | - | - | 30 | **B** | 44 | **A** |
| 2012 | - | - | 30 | **B** | 46 | **A** |
| 2013 | - | - | 34 | **A** | 42 | **A** |
| 2014 | - | - | 24 | **B** | 48 | **A** |
| 2015 | - | - | 24 | **B** | 48 | **A** |
| 2016 | 46 | **A** | 28 | **B** | 48 | **A** |
| 2017 | 42 | **A** | 24 | **B** | 48 | **A** |
| 2018 | 46 | **A** | 26 | **B** | - | - |
| 2019 | 44 | **A** | 22 | **B** | 44 | **A** |
| 2020 | 46 | **A** | 22 | **B** | 42 | **A** |
| Key: | A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) | | | | | |
| | B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) | | | | | |
| | C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) | | | | | |
| | D = Non Supporting / Severely Impaired (TMI Scores < 10) | | | | | |

Generally speaking, TMI Scores for Bear Creek are lowest at the upstream station (BCK 12.3) and highest at the most downstream station (BCK 3.3). BCK 12.3 displays a reduced benthic macroinvertebrate community. It consistently ranks among the poorest performing sites monitored in this project. On average, BCK 12.3 scores approximately 19 points lower per year than its corresponding reference station (Figure 3.1.5). Since 2014, the TMI score for BCK 12.3 has been in a gradual decline. The cause is unknown at this time. It is notable that reference station CCK 1.6 has shown a similar decline. In 2020, BCK 12.3 scored 20 points lower than CCK 1.6 (Table 3.1.6). This was expected and does not represent a drastic change from historical trends.

In 2020, BCK 3.3 had a TMI score of 46, outperforming reference station CCK 1.6 in many of the metrics (Table 3.1.7). This is likely due to the dilution of contaminants from Y-12 and greater habitat availability. BCK 3.3 is the farthest downstream site that TDEC DoR-OR monitors. It has a greater flow, a more natural substrate, and a pool to riffle ratio that is more conducive for macroinvertebrate habitation than reference station CCK 1.6.

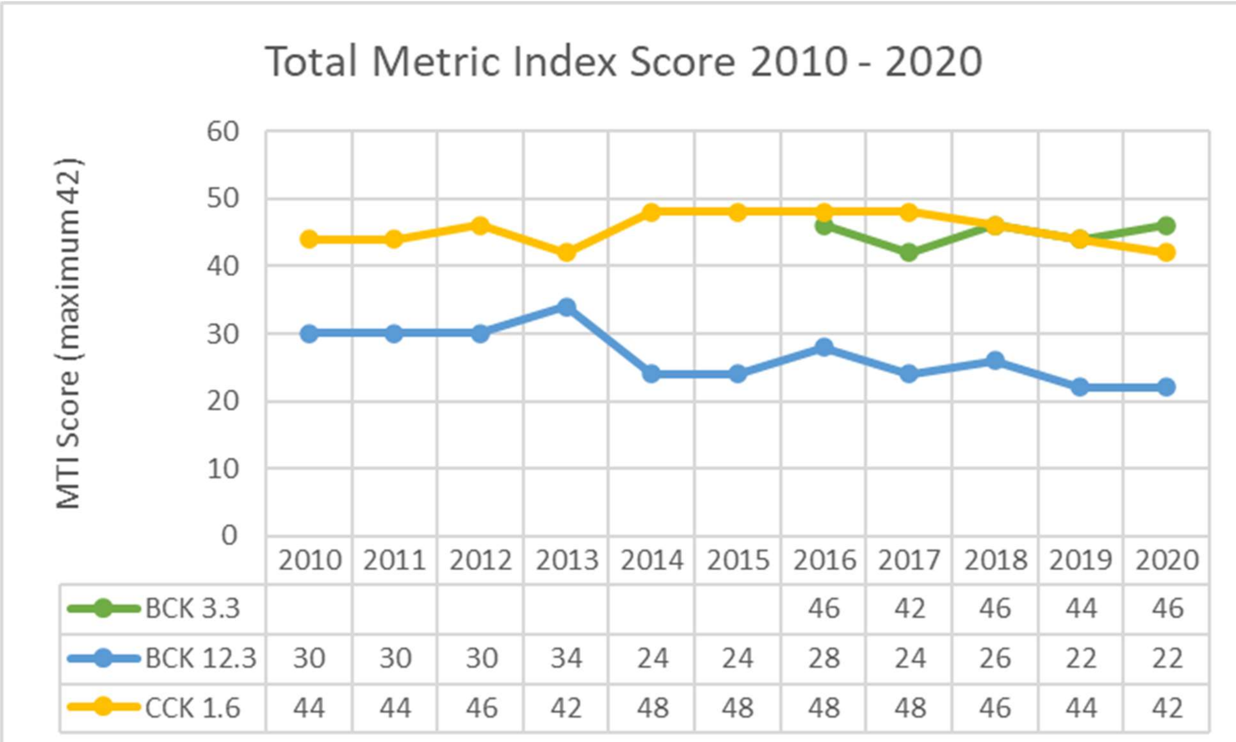



**Figure 3.1.5: Total Metric Index Scores for Bear Creek and Clear Creek Reference Station from 2010 - 2020**

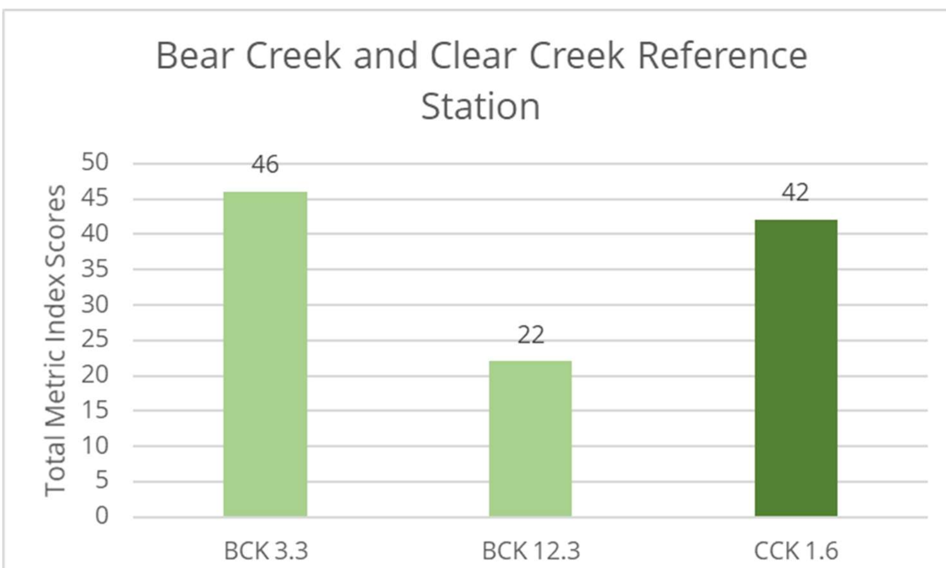



**Figure 3.1.6: 2020 Total Metric Index Scores in Bear Creek and Clear Creek Reference Station**

BCK 12.3 continues to receive the highest concentration of contaminants from Y-12 former and current waste sites and is subject to low flows for a significant portion of the year. The watershed upstream of BCK 12.3 is limited in size, thus affecting the amount of flow at the station, particularly in the summer. BCK 12.3 lacks adequate substrate for colonization by aquatic organisms. BCK 12.3 suffers from reduced aquatic macroinvertebrate refuges in its vicinity from which recolonization of the station can occur. Enhancing the stream bottom with more natural substrates would help remediate this stream by providing more habitat for the benthic communities.

**Table 3.1.7: Benthic Macroinvertebrate Metric results for Bear Creek and Clear Creek Reference Station**

| Benthic Macroinvertebrate Metrics Results | | | |
|---|---|---|---|
| | BCK 3.3 | BCK 12.3 | CCK 1.6 |
| Taxa Richness | 38 | 34 | 37 |
| EPT Richness | 11 | 6 | 17 |
| %EPT-CHEUM | 47.26% | 3.10% | 16.59% |
| %OC | 0.63% | 28.64% | 5.24% |
| NCIB | 4.15 | 6.22 | 4.92 |
| %Clingers | 74.89% | 40.21% | 64.19% |
| Tolerant Taxa | 19.20% | 65.04% | 33.84% |
| Intolerant Taxa | 7 | 7 | 14 |

**Mitchell Branch**

Mitchell Branch is a small headwater tributary to Poplar Creek at the ETTP. The highest upstream station, which serves as the reference station (MIK 1.43), does not meet the criteria for rating, according to the bioregion concept, due to the size of the watershed above it (<two square miles). Because of the small upstream watershed and variable flow conditions depending on annual rainfall, MIK 1.43 does not always provide a clear picture of the impacted condition of the downstream stations (MIK 0.71 and MIK 0.45). Historically, MIK 1.43 has been relatively unimpacted by the presence of ETTP. The lower station, MIK 0.45, has been impacted not only from former industrial activities at ETTP and waste areas but has also been channelized with much of the channel being replaced with unnatural substrate.

Over time, the substrate (stream bottom) is becoming more natural, allowing a more diverse community to inhabit those stations. Further improvements in substrate as well as water quality improvements due to remedial activities will allow Mitchell Branch to continue to improve.

**Table 3.1.8: Mitchell Branch TMI Scores and Biological Condition Ratings**

| Total Metric Index Scores and Biological Condition Rating | | | | |
|---|---|---|---|---|
| | MIK 0.45 | | MIK 1.43 | |
| | TMI | RATING | TMI | RATING |
| 2010 | 24 | **B** | 26 | **B** |
| 2011 | 20 | **C** | 24 | **B** |
| 2012 | 24 | **B** | 46 | **A** |
| 2013 | 24 | **B** | 42 | **A** |
| 2014 | 34 | **A** | 44 | **A** |
| 2015 | 28 | **B** | 44 | **A** |
| 2016 | 26 | **B** | 34 | **A** |
| 2017 | 30 | **B** | 36 | **A** |
| 2018 | 30 | **B** | 40 | **A** |
| 2019 | 34 | **A** | 28 | **B** |
| 2020 | 22 | **B** | 44 | **A** |
| Key: | A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) | | | |
| | B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) | | | |
| | C = Partially Supporting / Moderately Impaired (TMI Scores 10 - | | | |
| | D = Non Supporting / Severely Impaired (TMI Scores < 10) | | | |

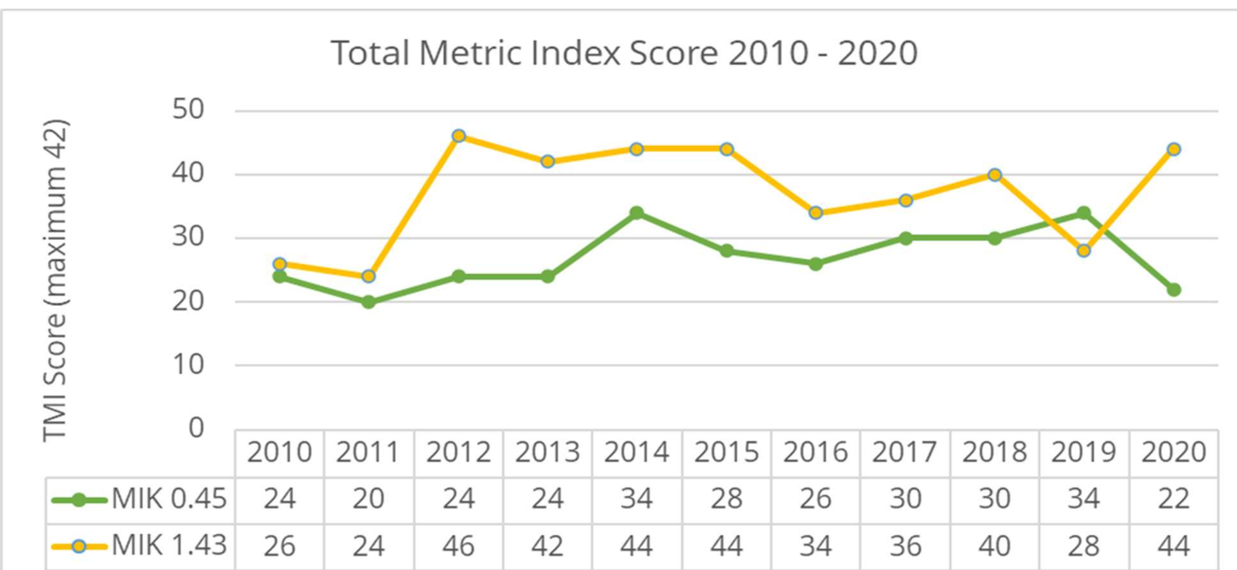



**Figure 3.1.7: Total Metric Index Scores in Mitchell Branch from 2010 - 2020**

Between 2010 and 2019, MIK 0.45 showed improvement in its TMI (Table 3.1.8). The TMI score for MIK 0.45 dropped sharply from historical trends in 2020 (Figure 3.1.7). At this time, the specific cause for this reduction in TMI is unknown.

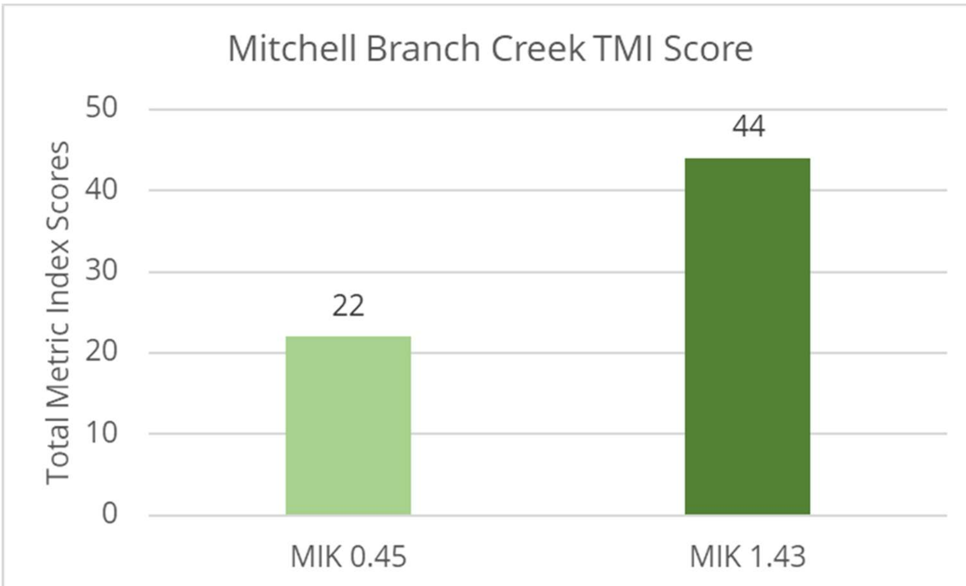



**Figure 3.1.8: 2020 Total Metric Index Scores in Mitchell Branch**

MIK 0.45 did not compare well with its upstream reference station MIK 1.43 in 2020 (Figure 3.1.8). Unlike other streams on the ORR, Mitchell Branch experiences larger swings in water quality on a seasonal basis. Specifically, TDEC DoR-OR staff have observed wide swings in dissolved oxygen in Mitchell Branch. MIK 0.45 is susceptible to scouring during rain events that can quickly wipe out the benthic community. Oak Ridge received 1.13 inches of rain ten days prior to macroinvertebrate collection in 2020. Additionally, high levels of mercury were noted discharging from outfall 180 into Mitchell Branch during the summer of 2020. These factors potentially contributed to the reduction in TMI at MIK 0.45.

**Table 3.1.9: Benthic Macroinvertebrate Metric results for Mitchell Branch**

| Benthic Macroinvertebrate Metrics Results | | |
|---|---|---|
| | MIK 0.45 | MIK 1.43 |
| Taxa Richness | 21 | 31 |
| EPT Richness | 2 | 10 |
| %EPT-CHEUM | 6.18% | 34.11% |
| %OC | 2.81% | 0.93% |
| NCIB | 4.36 | 5.41 |
| %Clingers | 79.21% | 55.61% |
| Tolerant Taxa | 32.58% | 40.65% |
| Intolerant Taxa | 2 | 6 |

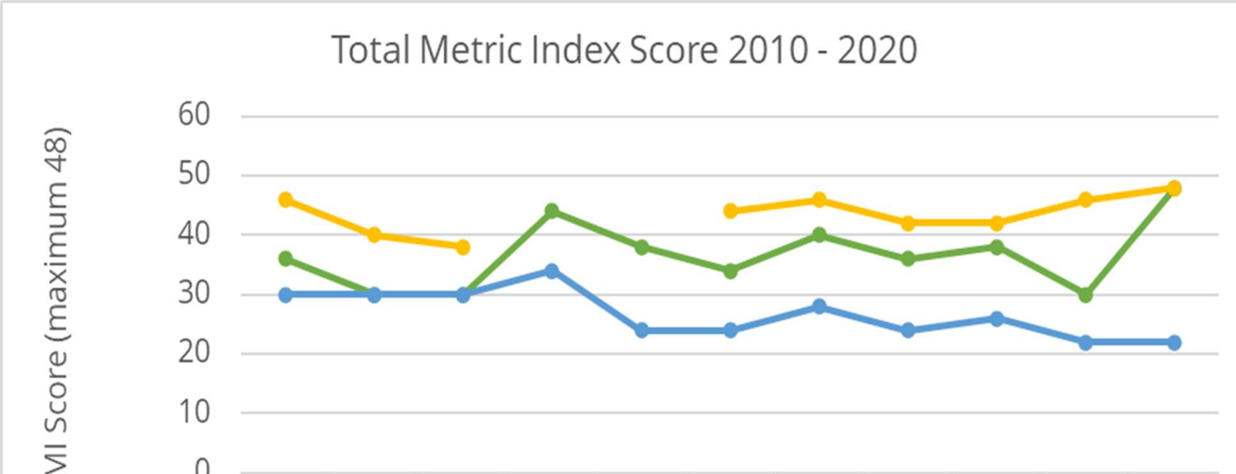
**White Oak Creek and Melton Branch**

WOC is the main drainage for the majority of ORNL's disturbed areas. It flows from its headwaters near the Spallation Neutron Source and through the main plant area in Bethel Valley, then into Melton Valley, flowing through the Solid Waste Storage Areas and entering White Oak Lake before exiting the reservation through White Oak Embayment and flowing into the Clinch River. Melton Branch drains the eastern portion of Melton Valley with the sampling station MEK 0.3 located near the High Flux Isotope Reactor facility. Parts of Melton Branch have been channelized. WCK 3.9 is located on the south side of the ORNL complex and downstream of Fifth Creek, which receives inputs from a large part of the main campus of ORNL. This station at one time was impacted heavily by discharges, spills, and former waste sites.

Traditionally, all samples were collected in the field, preserved in ethanol, and returned to the TDEC DoR-OR laboratory for processing; however, processing samples in the TDEC DoR-OR laboratory left radioactive sediments to be properly disposed. In 2015, the decision was made to process WOC contaminated sites in the field to avoid having to return sediments to the laboratory. In 2020, all contaminated sites were processed in the field removing all organisms and returning the sediments to the site of their origin. Macroinvertebrate specimens were identified in the TDEC DoR-OR laboratory.

**Table 3.1.10: Total Metric index Scores in WOC, Melton Branch, and Hinds Creek Reference Stream**

| Total Metric Index Scores | | | | | | |
|---|---|---|---|---|---|---|
| | MEK 0.3 | | WCK 3.9 | | HCK 20.6 | |
| | TMI | RATING | TMI | RATING | TMI | RATING |
| 2010 | 36 | **A** | 30 | **B** | 46 | **A** |
| 2011 | 30 | **B** | 30 | **B** | 40 | **A** |
| 2012 | 30 | **B** | 30 | **B** | 38 | **A** |
| 2013 | 44 | **A** | 34 | **A** | - | - |
| 2014 | 38 | **A** | 24 | **B** | - | - |
| 2015 | 34 | **A** | 24 | **B** | 44 | **A** |
| 2016 | 40 | **A** | 28 | **B** | 46 | **A** |
| 2017 | 36 | **A** | 24 | **B** | 42 | **A** |
| 2018 | 38 | **A** | 26 | **B** | 42 | **A** |
| 2019 | 30 | **B** | 22 | **B** | 46 | **A** |
| 2020 | 48 | **A** | 22 | **B** | 48 | **A** |
| Key: | A = Supporting / Non Impaired (TN Macro. Index Scores >= 32)<br>B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31)<br>C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20)<br>D = Non Supporting / Severely Impaired (TMI Scores < 10) | | | | | |




| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MEK 0.3 | 36 | 30 | 30 | 44 | 38 | 34 | 40 | 36 | 38 | 30 | 48 |
| WCK 3.9 | 30 | 30 | 30 | 34 | 24 | 24 | 28 | 24 | 26 | 22 | 22 |
| HCK 20.6 | 46 | 40 | 38 | | | 44 | 46 | 42 | 42 | 46 | 48 |

**Figure 3.1.9: Total Metric Index Scores for Melton Branch, WOC, and Hinds Creek Reference Station from 2010 – 2020**

WOC and Melton Branch typically have lower TMI scores than their corresponding reference location. However, MEK 0.3 has shown gradual improvement between 2010 and 2020 (Figure 3.1.9). MEK 0.3 has had a biological condition rating “Supporting/Not Impaired” seven out of the last 10 years (Table 3.1.10). In 2020, MEK 0.3 and reference station HCK 20.6 had a maximum TMI score of 48 (Table 3.1.10).

The TMI score for WCK 3.9 has been declining slowly over the past decade (Figure 3.1.9). In 2020, WCK 3.9 had a TMI score of 22. This was expected and does not indicate a significant change from historical trends. It is unclear at this time what is directly causing this decline, however recent industrial activity at ORNL may be a contributing factor.

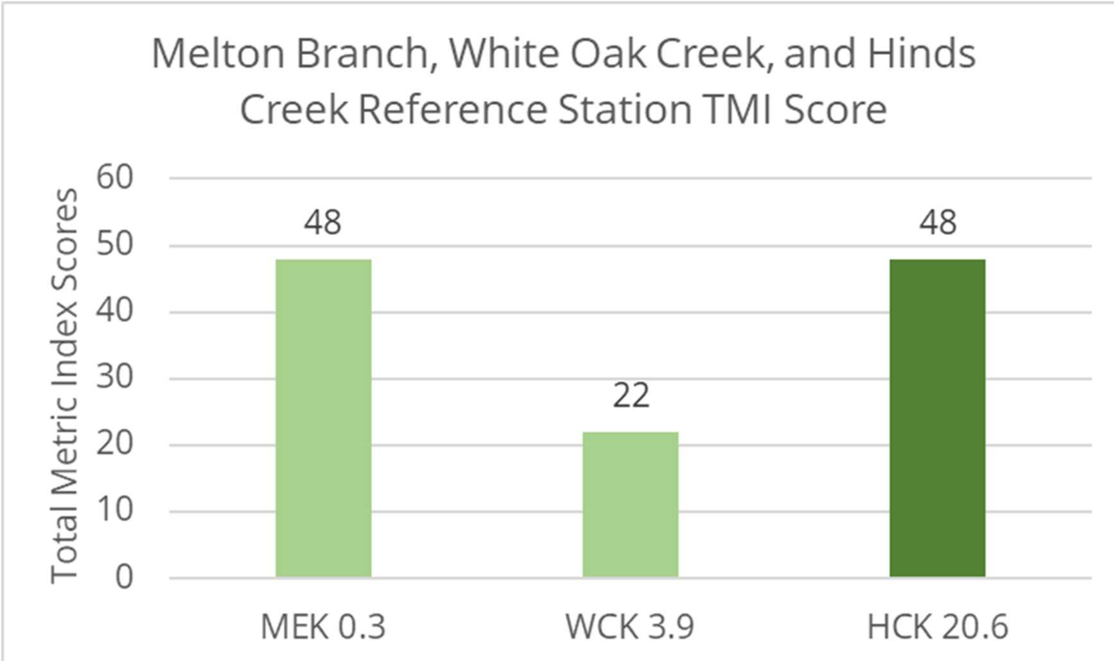



**Figure 3.1.10: 2020 TMI Score for Melton Branch, WOC, and Hinds Creek Reference Station**

**Table 3.1.11: Benthic Macroinvertebrate Results for Melton Branch, WOC, and Hinds Creek Reference Location**

| **Benthic Macroinvertebrate Metrics Results** | | | |
|---|---|---|---|
| | MEK 0.3 | WCK 3.9 | HCK 20.6 |
| Taxa Richness | 24 | 11 | 40 |
| EPT Richness | 8 | 2 | 18 |
| %EPT-CHEUM | 28.78% | 9.02% | 23.69% |
| %OC | 35.83% | 4.10% | 2.71% |
| NCIB | 4.64 | 5.90 | 3.83 |
| %Clingers | 91.37% | 78.69% | 75.41% |
| Tolerant Taxa | 41.87% | 59.84% | 28.75% |
| Intolerant Taxa | 7 | 2 | 10 |

### 3.1.8 Conclusions

The health of the benthic macroinvertebrate communities in ORR streams has improved since the 1980's. This improvement has leveled off and stabilized for the past few years. In 2020, results from the Benthic Macroinvertebrate Monitoring Project measured similarly to recent year's trends.

The Y-12 watershed, EFPC and Bear Creek, continues to show impairment at the headwaters closest to DOE facilities and industrial activities. EFK 25.1 had the lowest TMI score on the ORR in 2020. BCK 12.3 had the second lowest score on the ORR in 2020. This was expected and does not represent a drastic change from historical trends. Macroinvertebrate communities improve downstream as they get farther away from the sources of contamination. BCK 3.3 and EFK 6.3 were considered "Supporting/Non-Impaired" in 2020.

The ORNL watershed, WOC and Melton Branch, has been relatively stable over the past decade, with only slight variation year-to-year. WCK 3.9 and MEK 0.3 scored similarly to past years. This was expected and does not represent a drastic change from historical trends.

The ETTP watershed, Mitchell Branch, shows the largest variation in TMI scores year-to-year. Mitchell Branch is smaller than other streams monitored on the ORR and is more susceptible to both natural and anthropomorphic stressors. In 2020, MIK 0.45 had a sharper decrease in TMI than the previous 10 years. This may be due to a large rain event that occurred ten days prior to collection or high levels of mercury in May 2020 from ETTP outfall 190.

### 3.1.9 Recommendations

Benthic communities in streams on the ORR should continue to be monitored on a regular basis. Changes in the condition of these communities (improvement or otherwise) serve as an indicator of positive remediation effects or negative effects of pollution. Every effort should be made to protect the current quality of streams that meet their designations and to improve those that do not.

### 3.1.10 References

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## 3.2 ORR Roving Creel Survey

### 3.2.1 Background

The Roving Creel Survey project evaluated the level of angler activity and estimated angling pressure at three key locations where impaired Oak Ridge Reservation (ORR) watersheds drain into publicly accessible waters. Fisherman interviews were conducted at the confluence region of White Oak Creek Embayment and the Clinch River, the confluence of Poplar Creek and the Clinch River, and the confluence region of East Fork Poplar Creek (EFPC) and Poplar Creek. These streams have been negatively impacted by Manhattan Project activities as well as current operational activities.

Bear Creek and EFPC originate within the confines of the Y-12 Nuclear Industrial Complex (Y-12) and are fed by springs and numerous outfalls from various plant facilities. During the 1950's and early 1960's, processes and practices of the ORR nuclear weapons program at Y-12 led to the release of large amounts of mercury and other contaminants to the local environment (Brooks et al., 2017). Mercury and other contaminants such as radionuclides were released in a wide range of concentrations to surface waters, sediments, and floodplain soils (Pant et al., 2010).

Mercury in streams and wetlands often undergoes methylation and is transformed into toxic methylmercury (MeHg) in conjunction with the activity of microorganisms (Kalisinska et al., 2013). Methylmercury is particularly bioavailable to wildlife (and humans) and, if ingested, may cause serious neurological, reproductive, and other physical damage (Standish, 2016). Fish are especially vulnerable to mercury bioaccumulation due to their habitat and diet.

White Oak Creek originates just north of the Oak Ridge National Laboratory (ORNL), cuts through the main campus, and discharges into the Clinch River. Radionuclides released from ORNL to the water pathway are leaked from ponds and waste disposal areas and include contaminants such as strontium-90 (Sr-90) and cesium-137 (Cs-137), as well as other byproducts (DOE, 1988). These are significant because of their radiotoxicity, their mobility in the environment, and the quantities released. Other radionuclides of significance include tritium and transuranics (DOE, 1988). The availability of Cs-137 for biological uptake is a major public health concern as it can be transferred to humans through food webs (Ashraf et al., 2014). Even in the most mobile aquatic habitats (i.e., flowing rivers), cesium may persist in a biologically available form for several years after release (Ashraf et al., 2014).

Little is known about the level of human interaction with these publicly accessibly waters. Some contaminants could be harmful to human health in large quantities and prolonged exposures. Consumption of fish is the most likely human exposure pathway. According to a fish consumption survey conducted in 2008, approximately two thirds of fishermen consumed fish from the waters in the Melton Hill and Blair Creek Road area (Campbell, 2002). 80% of those interviewed were aware of fish consumption advisories (Campbell, 2002). Of those, almost 50% still thought the fish were safe to eat (Campbell, 2002). The fish consumption study overlaps many of the areas in this roving creel survey project. Currently, our data are not sufficient to determine if enough protective measures are being implemented to limit human exposure on the ORR.

### 3.2.2 Problem Statements

- Fish bioaccumulate mercury and other contaminants produced on the ORR.

- Fish-consumption warnings are often not visible, missing, or disregarded by the public.
- Although studies have been conducted to evaluate fish consumption habits of fishermen, there are no data to assess the extent of human interaction with fish taken from exit pathways on the ORR.

### 3.2.3 Goals

- To measure the fishing effort at key locations on the ORR where potential human exposure to mercury and other contaminants may exist.

### 3.2.4 Scope

This project was limited to three primary locations: These targeted areas cover approximately 100 square acres each. They are all accessible from a centrally located boat launch.

Zone 1: the downstream confluence region of White Oak Creek Embayment and the Clinch River (Figure 3.2.1),

Zone 2: the downstream confluence region of Poplar Creek and the Clinch River (Figure 3.2.2),

Zone 3: the downstream confluence region of East Fork Poplar Creek and Poplar Creek (Figure 3.2.3).


**Figure 3.2.1: (Zone 1) Confluence region of White Oak Creek Embayment and the Clinch River**

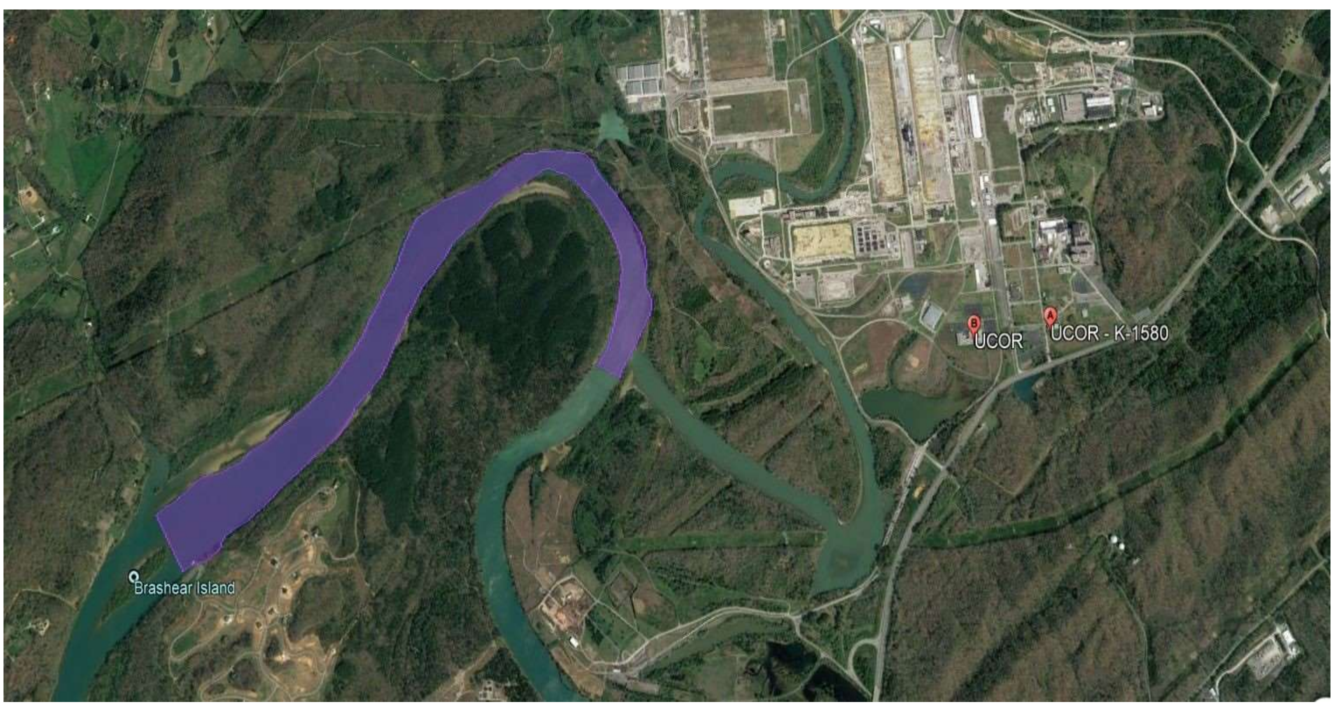


**Figure 3.2.2: (Zone 2) Confluence region of Poplar Creek and the Clinch River**


**Figure 3.2.3: (Zone 3) Confluence region of East Fork Polar Creek and Poplar Creek**

TDEC DoR-OR personnel made every effort to conduct five (5) roving creel survey events per quarter for a goal of twenty (20) sampling events in Fiscal Year 2021, between 07/01/20 and 06/30/21. Due to inclement weather, fifteen (15) events were successfully completed. Dates selected for sampling events used non-uniform probability, stratified random sampling to maximize sampling efficiency and minimize bias. A randomized sampling schedule was created prior to the beginning of the survey year.

## 3.2.5 Methods, Materials, Metrics

TDEC DoR-OR personnel conducted surveys at three locations with active, on-site methods whereby anglers were interviewed either before, during, or immediately following fishing trips. All waterbodies were sampled using roving creel survey methods, outlined in the TWRA 2007 Fisheries Report.

A roving creel survey sample consists of two parts: angler counts and angler interviews. Counts of anglers were taken within the sample period by making a circuit of the lake concurrently with interviews during a single circuit of the waterbody section within a ½-day sampling period (count-as-you-go method). All anglers fishing from either boats or from the shore were counted.

Upon approaching anglers, TDEC DoR-OR personnel recorded information, which does not require interrupting fishing, including date, location, sample area, fishing from the bank or a boat, and the number of anglers in the fishing party. When the TDEC DOR-OR personnel reached the angler or angling group, they asked if they would mind spending a few moments answering questions related to their fishing trip. If anglers did not wish to be interrupted, then the TDEC DoR-OR personnel moved on.

Anglers who agreed to be interviewed were asked the following questions:

- What time did you start fishing today?
- How much longer do you expect to fish?
- What is your primary target species?
- What state and county are you from?
- How frequently do you fish in this area?

Fishing Effort:

Estimates of fishing effort were calculated using daily angler counts and the number of hours reported within a sample period. Thus, for any given sampling period, fishing effort measured in angler hours (e) was calculated as the product of the total angler count (c) and the number of hours reported during that sampling period (h), or e=c(h). This value estimates total angler-hours for a single lake section within a single time period. This estimate can be expanded to estimate angler hours for the whole day by dividing (e) by the probability for the secondary sampling unit (time period/lake section) worked that day.

This roving creel survey divided the day into two equal parts, morning and evening. All surveys were performed during the morning section over the same three 100-acre sections. Following TWRA's methodologies, TDEC DoR-OR personnel assumed that morning and evening fishermen counts are roughly equal and provide an adequate approximation of fishermen activity over the course of a whole day for the purpose of this study. Thus, the time period probability was 0.5 and the lake section was 1.0, therefore the secondary sampling unit probability was 0.5. If (e)=100, then 100/0.5 = 200 angler hours for the whole area for that entire day (E).

To derive estimates of total quarterly fishing effort, whole day angler hours were multiplied by the number of days within that quarter. TDEC's fiscal year runs July 1st – June 30th.

- Quarter 1 = 92 days (July – September)
- Quarter 2 = 92 days (October – November)
- Quarter 3 = 90 days (January – March)
- Quarter 4 = 91 days (April – June)

All work on this project follows the requirements of TDEC Division of Remediation Oak Ridge *Office Health and Safety Plan* (TDEC, 2020).

### 3.2.6 Deviations from the Plan

Because the sampling events were predetermined, there were instances where inclement weather could not be avoided. For the safety of staff, TDEC DoR-OR did not operate the boat during unsafe weather conditions. Every effort was made to reschedule sampling events to the following week during a similar timeslot to avoid influencing the random nature of the sample schedule. Five sampling events were canceled after multiple instances of inclement weather.

### 3.2.7 Results and Analysis

Notable Angler Observations:

- 36 fishing vessels were encountered in FY 2021.
- 83 individuals were observed fishing during that time.
- 81 agreed to participate in the survey.
- 43 individuals, or 53%, of the participants described themselves as "locals".
- 38 individuals, or 47%, of the participants described themselves as "visiting".
- Seven states are represented among anglers that described themselves as "visiting": NC, SC, KS, VA, OK, GA, and TN (visiting anglers from TN traveled greater than 100 miles).
- 67 individuals, or 81%, of the participants were private fishing vessels.
- 16 individuals, or 19%, of the participants were commercial fishing charters.

Notable Angler Comments:

- On September 4th, TDEC DoR-OR personnel spoke with an individual that had been given the same survey two days prior. He said that he plans a weeklong trip to this area and to Lake Norris every year.
- On November 1st, TDEC DoR-OR personnel spoke with a party from Blount County that described himself as a regular fisherman. He had significant complaints about the quality of fishing in recent years. He noted that sedimentation in the Clinch and Poplar Creek may be the cause.
- On January 30th, TDEC DoR-OR personnel spoke with a party from Knox County that regularly fish in this area. They were observed collecting large branches from the wooded boat ramp parking lot. When asked, they stated that they were spending the day fishing for muskie and constructing additional natural habitat along the banks. They hoped that the additional habitat would increase their fishing success later in the year. They specifically mentioned that the "best" fishing locations in this area included Poplar Creek, just downstream of the Perimeter Road Bridge.
- On April 13th, TDEC DoR-OR personnel spoke with a party from Anderson County, TN. One individual said that TDEC DoR-OR had interviewed him previously during a different RCS event. He said that he fishes in this area frequently, at least once per week. He claimed that Poplar Creek is a "prime fishing spot" during the popular spring and fall fishing seasons.
- On June 23rd, TDEC DoR-OR personnel spoke with a party from Knox and Blount County. One individual from this vessel estimated that he's fished in this area more than 700 times. He stated that he keeps excellent records of his fishing trips and noticed that his fishing success has been in decline over the past few years. He noted that there has been a huge increase in angler activity in recent years mostly due to commercial fishing charters from out-of-town. He believes that the decrease in fishing success is due to overfishing and irresponsible fishing practices of these businesses. He is especially frustrated with their use of live bait, which he says kills the striped bass after they are thrown back.
- On June 23rd, TDEC DoR-OR personnel spoke to Bushwacker Guide Service, a commercial fishing charter from Lincoln County, NC. This was the fourth encounter TDEC DoR-OR personnel had with this group (previous surveys were conducted on July 12th, July 19th, and April 13th). This company has grown since TDEC DoR-OR's first encounter and has added additional boats to their fleet.

**Zone 1: The confluence region of White Oak Creek and the Clinch River**

Twelve unique vessels were interviewed in Zone 1, at the locations shown (Figure 3.2.4). Twenty-seven individual fishermen reported angling 157.5 total hours on sampling event days. Fishermen in Zone 1 reported fishing between 2.5 and 12.5 hours total on the day that they were interviewed. The average time reported spent on the water in this area was 5.3 hours. The median time reported spent on the water was 4.0 hours (Table 3.2.1). TDEC DoR-OR personnel estimate that fishermen angle for approximately 6621.8 hours in Zone 1 per year (Table 3.2.2).

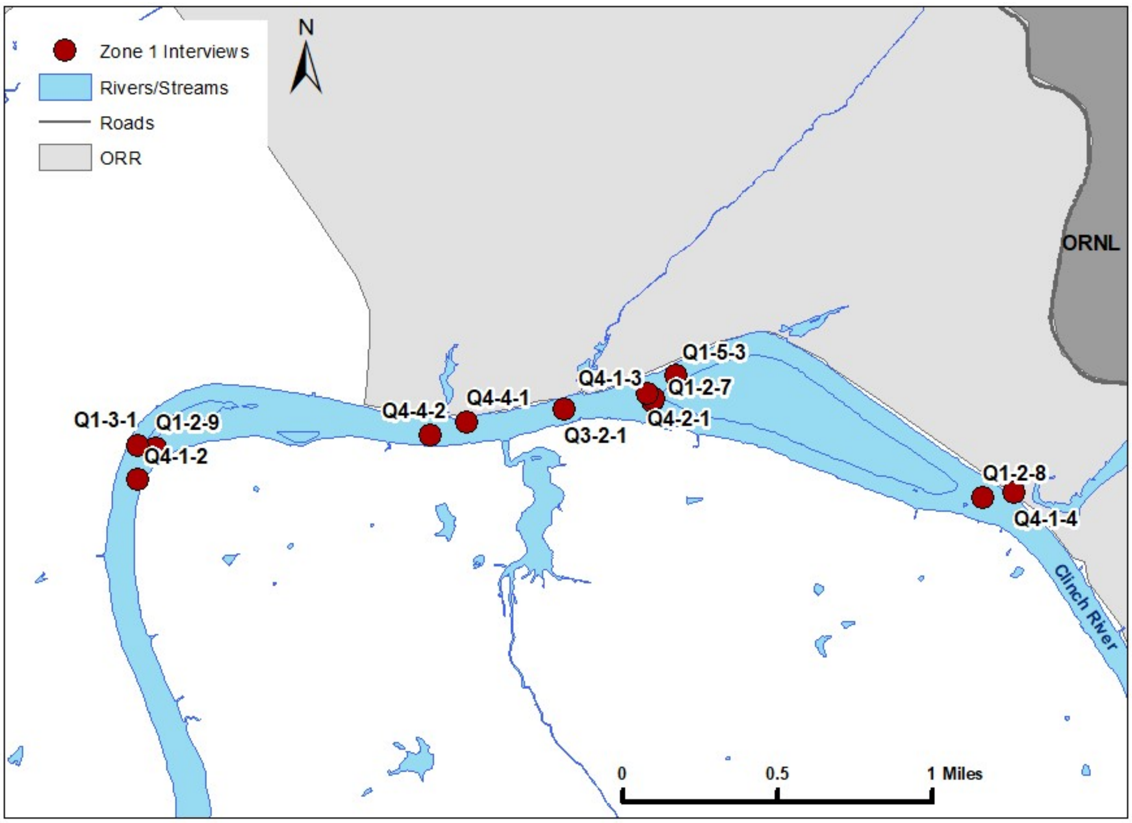


**Figure 3.2.4: Zone 1 Interview Locations**

**Table 3.2.1: Zone 1 Angler Counts and Reported Hours**

| Zone 1 Interviews | | | | | | | |
|---|---|---|---|---|---|---|---|
| Quarter-Event | Interview | ID | Date | Zone | Party Size | Reported | Total Hours |
| Q1-2 | 7 | Q1-2-7 | 7/19/2020 | 1 | 4 | 3.0 | 12.0 |
| Q1-2 | 8 | Q1-2-8 | 7/19/2020 | 1 | 2 | 5.0 | 10.0 |
| Q1-2 | 9 | Q1-2-9 | 7/19/2020 | 1 | 2 | 4.0 | 8.0 |
| Q1-3 | 1 | Q1-3-1 | 8/26/2020 | 1 | 2 | 5.5 | 11.0 |
| Q1-5 | 3 | Q1-5-3 | 9/4/2020 | 1 | 2 | 7.0 | 14.0 |
| Q3-2 | 1 | Q3-2-1 | 2/23/2021 | 1 | 2 | 4.0 | 8.0 |
| Q4-1 | 2 | Q4-1-2 | 4/13/2021 | 1 | 1 | 6.0 | 6.0 |
| Q4-1 | 3 | Q4-1-3 | 4/13/2021 | 1 | 3 | 4.0 | 12.0 |
| Q4-1 | 4 | Q4-1-4 | 4/13/2021 | 1 | 1 | 2.5 | 2.5 |
| Q4-2 | 1 | Q4-2-1 | 4/24/2021 | 1 | 2 | 5.0 | 10.0 |
| Q4-4 | 1 | Q4-4-1 | 6/23/2021 | 1 | 2 | 6.0 | 12.0 |
| Q4-4 | 2 | Q4-4-2 | 6/23/2021 | 1 | 4 | 12.0 | 48.0 |

**Table 3.2.2: Zone 1 Fishing Effort**

| Zone 1 | | |
|---|---|---|
| | Hours/Day | Hours/Quarter |
| Quarter 1 | 22.0 | 2024.0 |
| Quarter 2 | 0.0 | 0.0 |
| Quarter 3 | 5.3 | 480.0 |
| Quarter 4 | 45.3 | 4117.8 |
| Yearly | 72.6 | 6621.8 |

The Zone 1 region is approximately 100 square acres in size and receives inputs from White Oak Creek. Water exiting White Oak Creek is dammed to prevent larger quantities of contaminants from entering the Clinch River and referred to as the White Oak Creek Embayment. The primary contaminants of concern in this area are byproducts from historical nuclear activity as well as current industrial activities. These include cesium-137, strontium-90, and other fission daughter products. Signage is required to dissuade anglers from fishing directly in front of the White Oak Creek Embayment. TDEC DoR-OR personnel documented the current condition of the signage seen in Figure 3.2.5, Figure 3.2.6, and Figure 3.2.7.


**Figure 3.2.5: WOC Embayment Signage (left side)**


**Figure 3.2.6: WOC Embayment Signage (center)**


**Figure 3.2.7: WOC Embayment Signage (right side)**

TDEC DoR-OR personnel interviewed two vessels who were actively fishing within 50 feet and eyeshot of these signs. Interview Q1-2-8 was a vessel with two anglers fishing for striped bass and reported fishing that day for 4 hours. Interview Q4-1-4 was a vessel with one angler and was fishing for any bass species for 2.5 hours. The Q4-1-4 angler described himself as a local who regularly fishes in this area.

**Zone 2: Confluence region of Poplar Creek and the Clinch River**

Three unique vessels were interviewed in Zone 2 (Figure 3.2.8). Eight individual fishermen reported angling 58.5 total hours on sampling event days. Fishermen in Zone 2 reported fishing between 2.5 and 12 hours total on the day that they were interviewed. The average time reported spent on the water in this area was 7.8 hours (Table 3.2.3). TDEC DoR-OR personnel estimate that fishermen angle for approximately 3041.8 hours in Zone 2 per year (Table 3.2.4).

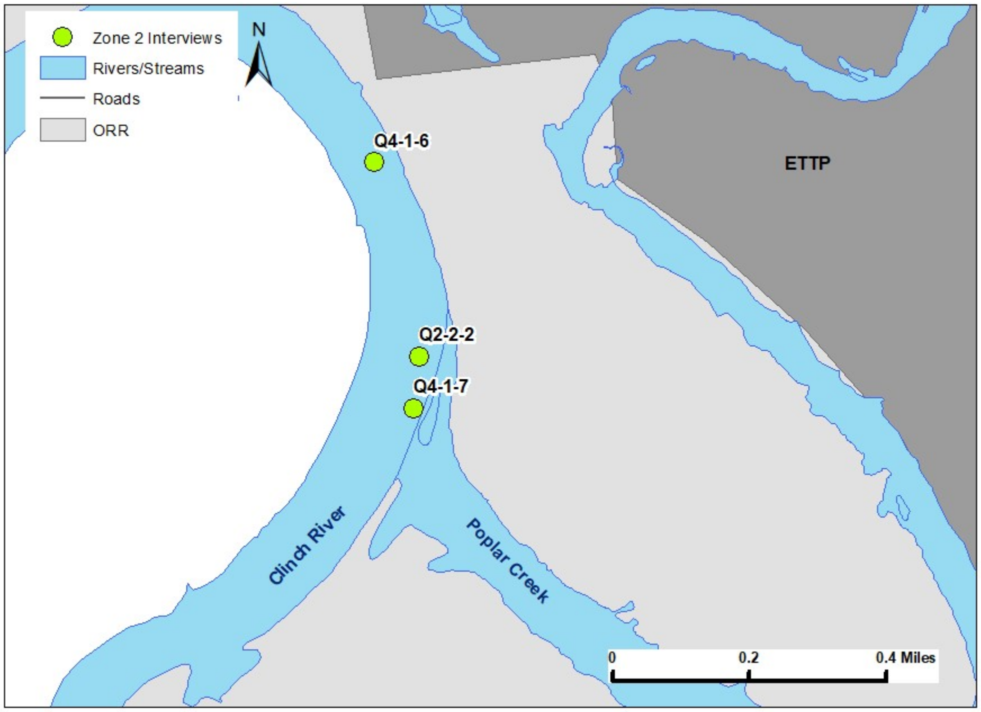


**Figure 3.2.8: Zone 2 Interview Locations**

**Table 3.2.3: Zone 2 Angler Counts and Reported Hours**

| Zone 2 Interviews | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Quarter-Event | Interview | ID | Date | Lat (DM) | Long (DM) | Zone | Party Size | Reported Hours | Total Hours |
| Q2-2 | 2 | Q2-2-2 | 11/1/20 | 35.927628 | -84.40948 | 2 | 2 | 12.0 | 24 |
| Q4-1 | 6 | Q4-1-6 | 4/13/21 | 35.930947 | -84.410418 | 2 | 3 | 9.0 | 27 |
| Q4-1 | 7 | Q4-1-7 | 4/13/21 | 35.926742 | -84.409602 | 2 | 3 | 2.5 | 7.5 |

**Table 3.2.4: Zone 2 Fishing Effort**

| Zone 2 Fishing Effort | | |
|---|---|---|
| | Hours/Day | Hours/Quarter |
| Quarter 1 | 0.0 | 0.0 |
| Quarter 2 | 16.0 | 1472.0 |
| Quarter 3 | 0.0 | 0.0 |
| Quarter 4 | 17.3 | 1569.8 |
| Yearly | 33.3 | 3041.8 |

**Zone 3: Confluence region of East Fork Poplar Creek and Poplar Creek**

Five unique vessels were interviewed in Zone 3 (Figure 3.2.9). Nine individual fishermen reported angling 35.5 total hours on sampling event days. Fishermen in Zone 3 reported fishing between 2.5 and 12 hours total on the day that they were interviewed. The average time reported spent on the water in this area was 7.8 hours (Table 3.2.5). TDEC DoR-OR personnel estimate that fishermen angle for approximately 3041.8 hours in Zone 2 per year (Table 3.2.6).

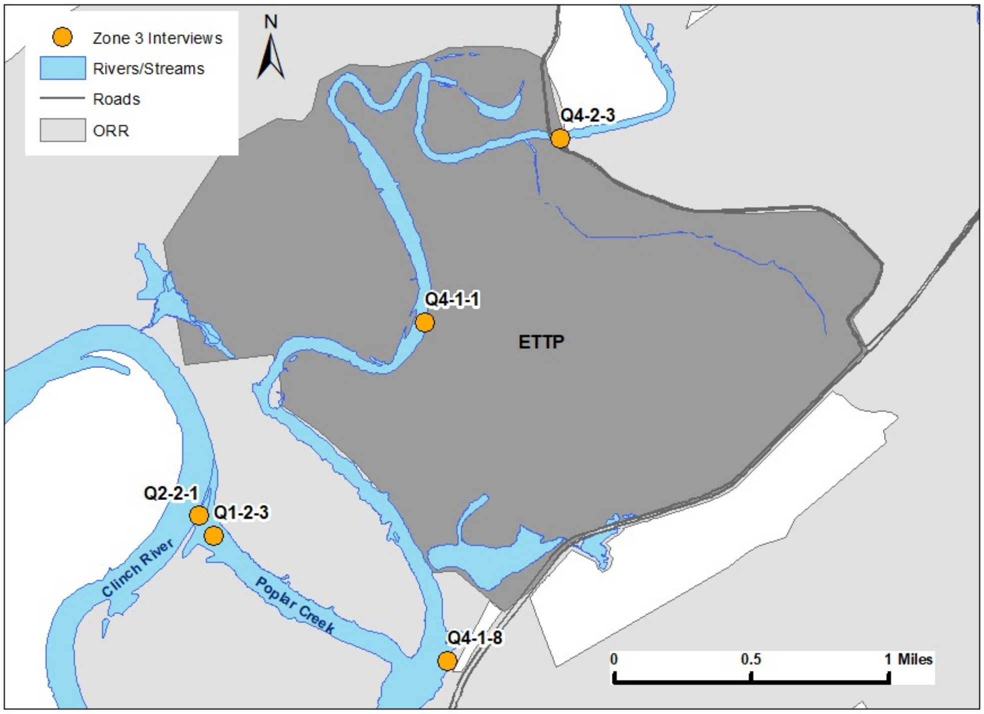


**Figure 3.2.9: Zone 3 Interview Locations**

**Table 3.2.5: Zone 3 Angler Counts and Reported Hours**

| Zone 3 Interviews | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Quarter-Event | Interview | ID | Date | Lat (DM) | Long (DM) | Zone | Party Size | Reported Hours | Total Hours |
| Q1-2 | 3 | Q1-2-3 | 7/19/20 | 35.925078 | -84.40889 | 3 | 2 | 3.0 | 6 |
| Q2-2 | 1 | Q2-2-1 | 11/1/20 | 35.925925 | -84.40966 | 3 | 2 | 3.0 | 6 |
| Q4-1 | 1 | Q4-1-1 | 4/13/21 | 35.934167 | -84.397778 | 3 | 2 | 5.0 | 10 |
| Q4-1 | 8 | Q4-1-8 | 4/13/21 | 35.919757 | -84.396571 | 3 | 1 | 5.5 | 5.5 |
| Q4-2 | 3 | Q4-2-3 | 4/26/21 | 35.942008 | -84.390605 | 3 | 2 | 4.0 | 8 |

**Table 3.2.6: Zone 3 Fishing Effort**

| Zone 3 | | |
|---|---|---|
| | Hours/Day | Hours/Quarter |
| Quarter 1 | 2.4 | 220.8 |
| Quarter 2 | 4.0 | 368.0 |
| Quarter 3 | 0.0 | 0.0 |
| Quarter 4 | 11.8 | 1069.3 |
| Yearly | 18.2 | 1658.1 |

Surveys conducted in FY 2021 suggest that the Zone 3 region is typically utilized by locals. These locals regard Poplar Creek as a “prime fishing spot” during the spring and fall fishing seasons, when the Clinch River is crowded. Most fishermen do not angle in the area upstream of the first bridge. There are large concrete pilings partially submerged under the bridge that most consider imposing obstacles. However, the bridge can be passed by going between the pilings where the water depth is approximately eight feet deep in most places. Some fishermen specifically seek out this this location due to its seclusion.

One group of fishermen told TDEC DoR-OR personnel that they were heading there to construct natural habitats out of fallen branches along the bank of the creek to increase their angling success later in the year. They told TDEC DoR-OR personnel that the best fishing locations are the small creeks and canals that feed into the Clinch River. They specifically mentioned that Poplar Creek, just downstream of the first bridge was one of the best fishing locations.

Although no fishermen were surveyed upstream of the Perimeter Road Bridge, evidence of bank fishing was found on several occasions. Discarded fishing lines, fisherman trails, and a makeshift boat ramp can be observed in Figure 3.2.10, Figure 3.2.11, and Figure 3.2.12.

**Figure 3.2.10: Discarded Fishing Line on Poplar Creek near Blair Road Bridge**

**Figure 3.2.11: Fisherman's path from Blair Road to the North Bank at the confluence of EFPK and PC**

**Figure 3.2.12: Recent boat access, approximately 100 meters upstream of Blair Road Bridge**

All TDEC DoR-OR angler interviews are presented in Table 3.2.7 below.

## Table 3.2.7: All Angler Interviews

| FY2020/2021 Angler Interviews | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Location | | | Fishing | Residence | | | | | |
| | Date | Lat (DM) | Long (DM) | Party Size | Hours | County | State | Local (Yes/No) | | Target Species | Notes/Comments |
| Q1-1 Interview 1 | 7/12/2020 | 35.89657 | -84.387842 | 3 | 3.0 | Lincoln | NC | No | Commercial | Striped Bass | Bushwacker Guide Service, a commercial fishing charter from Lincoln County, NC. TDEC-DoR-OR personnel exchanged contact information to discuss commecial fishing on the Clinch River. **Note:** Bushwaker Guide Service requested that TDEC-DoR-OR do not inturrupt thier business in the future. Details from this interview can be replicated if their vassel is seen in this area again. |
| Q1-1 Interview 2 | 7/12/2020 | 35.88512 | -84.384267 | 2 | 4.0 | Knox | TN | Yes | Private | Striped Bass | No Comment |
| Q1-1 Interview 3 | 7/12/2020 | 35.90856 | -84.394772 | 1 | 3.0 | Knox | TN | Yes | Private | Striped Bass | No Comment |
| Q1-2 Interview 1 | 7/19/2020 | 35.91214 | -84.405939 | 3 | 5.0 | Lincoln | NC | No | Commercial | Striped Bass | Bushwacker Guide Service |
| Q1-2 Interview 2 | 7/19/2020 | 35.91513 | -84.414225 | 1 | 5.0 | | TN | Yes | Private | Striped Bass | No Comment |
| Q1-2 Interview 3 | 7/19/2020 | 35.92508 | -84.408894 | 2 | 3.0 | | TN | Yes | Private | Any Species | No Comment |
| Q1-2 Interview 4 | 7/19/2020 | 35.89899 | -84.387481 | 2 | 5.0 | | TN | Yes | Private | Striped Bass | No Comment |
| Q1-2 Interview 5 | 7/19/2020 | 35.88186 | -84.373278 | 1 | 8.0 | | TN | Yes | Private | Striped Bass | No Comment |
| Q1-2 Interview 6 | 7/19/2020 | 35.88265 | -84.372394 | 1 | 4.0 | | TN | Yes | Private | Striped Bass | No Comment |
| Q1-2 Interview 7 | 7/19/2020 | 35.90005 | -84.349808 | 4 | 3.0 | | SC | No | Private | Striped Bass | No Comment |
| Q1-2 Interview 8 | 7/19/2020 | 35.89641 | -84.334369 | 2 | 5.0 | | TN | Yes | Private | Striped Bass | No Comment |
| Q1-2 Interview 9 | 7/19/2020 | 35.89831 | -84.373003 | 2 | 4.0 | | TN | Yes | Private | Striped Bass | No Comment |
| Q1-3 Interview 1 | 8/26/2020 | 35.89839 | -84.373819 | 2 | 5.5 | Knox | TN | Yes | Private | Largemouth Bass | No Comment |
| Q1-4 Interview 1 | 9/2/2020 | 35.90817 | -84.393886 | 1 | 13.0 | Sedgwick | KS | No | Private | Muskie | No Comment |
| Q1-4 Interview 2 | 9/2/2020 | 35.88834 | -84.389289 | 1 | 13.0 | Sumner | TN | No | Private | Muskie | No Comment |
| Q1-5 interview 1 | 9/4/2020 | 35.9012 | -84.388142 | 1 | 13.0 | Sumner | TN | No | Private | Muskie | This individual had been given the same survey two days prior. He said that he plans a weeklong trip to this area and to Lake Norris every year. |
| Q1-5 interview 2 | 9/4/2020 | 35.88272 | -84.372269 | 2 | 11.0 | Wythe | VA | No | Private | Catfish | No Comment |
| Q1-5 interview 3 | 9/4/2020 | 35.90104 | -84.348697 | 2 | 7.0 | Knox | TN | Yes | Private | Largemouth Bass | No Comment |
| Q2-1 Interview 1 | ####### | null | null | null | null | null | null | null | null | null | Zero fishermen were encountered durring this sampling event. |
| Q2-2 Interview 1 | 11/1/2020 | 35.92593 | -84.409658 | 2 | 3.0 | Knox | TN | Yes | Private | Striped Bass | No Comment |
| Q2-2 Interview 2 | 11/1/2020 | 35.92763 | -84.409475 | 2 | 12.0 | Blount | TN | Yes | Private | All Bass | One individual from this party described himself as a regular fisherman. He had significant complaints about the quality of fishing in recent years. He noted that sedimentation in the Clinch and Poplar Creek may be the cause. |
| Q2-3 Interview 1 | 11/3/2020 | null | null | null | null | null | null | | null | null | Zero fishermen were encountered durring this sampling event. |
| Q3-1 Interview 1 | 1/30/2021 | 35.90742 | -84.393564 | 2 | 11.0 | Unicoi | TN | No | Private | Muskie | No Comment |

| FY2020/2021 Angler Interviews - Continued | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Location | | | Fishing | Residence | | | | | |
| | Date | Lat (DM) | Long (DM) | Party Size | Hours | County | State | Local (Yes/No) | | Target Species | Notes/Comments |
| Q3-1 Interview 2 | 1/30/2021 | 35.90722 | -84.393242 | 2 | 9.0 | Knox | TN | Yes | Private | Muskie | This party descibed themselves as regular fishermen. They were observed collecting large branches from the wooded boat ramp parking lot. When asked, they stated that they were spending the day fishing for muskie and constructing additional natural habitat along the banks. They hoped that the additional habitat would increase their fishing success later in the year. They specifically mentioned that the "best" fishing locations in this area included Poplar Creek, just downstream of the Perimeter |
| Q3-2 Interview 1 | 2/23/2021 | 35.89973 | -84.353928 | 2 | 4.0 | Knox | TN | Yes | Private | White Bass | No Comment |
| Q3-3 Interview 1 | 3/4/2021 | 35.90752 | -84.393886 | 2 | 4.0 | Knox | TN | Yes | Private | Any Species | No Comment |
| Q4-1 Interview 1 | 4/13/2021 | 35.93417 | -84.397778 | 2 | 5.0 | Anderson | TN | Yes | Private | Crappie | No Comment |
| Q4-1 Interview 2 | 4/13/2021 | 35.89711 | -84.373840 | 1 | 6.0 | Roane | TN | Yes | Private | Any Species | No Comment |
| Q4-1 Interview 3 | 4/13/2021 | 35.90016 | -84.349748 | 3 | 4.0 | | OK | No | Private | Crappie | No Comment |
| Q4-1 Interview 4 | 4/13/2021 | 35.89659 | -84.332915 | 1 | 2.5 | Knox | TN | Yes | Private | All Bass | No Comment |
| Q4-1 Interview 5 | 4/13/2021 | 35.91192 | -84.405782 | 6 | 8.0 | Lincoln | NC | No | Commercial | Striped Bass | Bushwacker Guide Service |
| Q4-1 Interview 6 | 4/13/2021 | 35.93095 | -84.410418 | 3 | 9.0 | Anderson | TN | Yes | Private | Striped Bass | No Comment |
| Q4-1 Interview 7 | 4/13/2021 | 35.92674 | -84.409602 | 3 | 2.5 | Knox | TN | Yes | Private | Striped Bass | No Comment |
| Q4-1 Interview 8 | 4/13/2021 | 35.91976 | -84.396571 | 1 | 5.5 | Knox | TN | Yes | Private | Striped Bass | No Comment |
| Q4-2 Interview 1 | 4/24/2021 | 35.90037 | -84.350033 | 2 | 5.0 | null | null | | Private | Striped Bass | No Comment |
| Q4-2 Interview 2 | 4/24/2021 | 35.92374 | -84.412718 | 8 | 6.0 | Various | GA | No | Private | Striped Bass | Fishing Club from Altlanta GA on their annual fishing trip. This was their first time fishing on the Clinch River. |
| Q4-2 Interview 3 | 4/24/2021 | 35.94201 | -84.390605 | 2 | 4.0 | Anderson | TN | Yes | Private | Striped Bass | No Comment |
| Q4-3 Interview 1 | 5/19/2021 | null | null | null | null | null | null | null | null | null | Zero fishermen were encountered durring this sampling event. |
| Q4-4 Interview 1 | 6/23/2021 | 35.89925 | -84.358473 | 2 | 6.0 | Knox | TN | Yes | Private | Striped Bass | Two retired men from Knox and Blount County. One individual from this vessel estimated that he's fished in this area more that 700 times. He stated that he keeps excellent records of his fishing trips and noticed that his fishing success has been in decline over the past few years. He noted that there has been a huge increase in angler activity in recent years mostly due to commercial fishing charters from out-of-town. He believes that the decrease in fishing success is due to overfishing and irresponsible fishing practices of these businesses. He is especially frustrated with their use of live bait, which he says kills the striped bass after they are thrown back. |
| Q4-4 Interview 2 | 6/23/2021 | 35.89877 | -84.360208 | 4 | 12.0 | Lincoln | TN | No | Commercial | Striped Bass | Bushwacker Guide Service, a commercial fishing charter from Lincoln County, NC. This was the fourth encounter TDEC-DoR-OR personnel had with this group (previous surveys were conducted on July 12th, July 19th, and April 13th). This company has grown since our first encounter and has added additional boats to their fleet. TDEC-DoR-OR personnel did not recognize thier new boat and spoke with a new boat capatin. |

### 3.2.8 Conclusions

Roving Creel Surveys were conducted on the Clinch River and Poplar Creek in Oak Ridge, TN in FY 2021. The RCS data suggest that there is more fishing activity near key ORR surface water exit points than previously thought. The area immediately downstream from the confluence of White Oak Creek Embayment area and the Clinch River (Zone 1) was the most popular among anglers with an estimated 6621.8 total Angler Hours per year. The area immediately downstream of the confluence of Poplar Creek and the Clinch River (Zone 2) had an estimated 3,041.8 total Angler Hours per year. The area immediately downstream of the confluence of East Fork Poplar Creek and Poplar Creek (Zone 3) was the second least popular with an estimated 1,658.1 total Angler Hours per Year.

53% of the individuals who participated in this study described themselves as locals. Many locals reported that they fish frequently and angle in this area often. These results suggest that there is potential for human exposure to contaminants through the consumption of fish, especially amongst locals.

### 3.2.9 Recommendations

Angler activity was found near ORR surface water exit points at a higher level than expected. TDEC DoR-OR is aware that concentrations of contaminants in the water are higher than background levels at these watersheds exit points. TDEC DoR-OR suggests that a more precise study be conducted to evaluate the potential human exposure risk of fishing in these publicly accessible waters.

Additional surveys collected from bank and shoreline fishermen is recommended in future studies. Trail cameras can be utilized to get an actual count of anglers who fish these waters. Fish tissue samples should be collected periodically to ensure that anglers are not exposed to high levels of ORR contamination. Additionally, signage needs more regular maintenance, with clear warnings about the level of risk anglers are taking by consuming fishes.

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## 3.3 Radiological Uptake in Food Crops

### 3.3.1 Background

In the ORR area, DOE has conducted sampling on locally grown and harvested food crops such as root crops (turnips), fruiting crops (tomatoes), and leaf crops (turnip greens, lettuce), and milk (cow) to ascertain possible impacts of environmental contamination and long-term accumulation of radionuclides to food crops consumed by residents of local communities. DOE suggested TDEC DoR-OR conduct similar sampling for comparison to DOE's results. This project serves to determine whether radionuclide contamination extends beyond the bounds of the ORR and is taken up into local food crops, hay, and milk.

DOE currently conducts and has previously conducted similar sampling as documented in the annual DOE Environmental Monitoring Plans and the yearly ASER reports for the ORR. DOE has sampled cow milk as recently as 2016 in Claxton (near the ORR) and in Maryville (reference location), but vegetables from the ORR (adjacent to air samplers) have not been sampled since 1996. Recent sampling from area farms and gardens surrounding the ORR has been completed by DOE and is noted in each year's ORR ASER (DOE, 2020). The milk sampling by DOE has not been done since 2016 because a local dairy was not found for sample collection.

### 3.3.2 Problem Statements

- Radiological materials from DOE operations have been released into the atmosphere, groundwater, surface water, soils, and sediment.
- Members of the public have the potential to be exposed to doses of radiological contaminants through the consumption of locally grown food crops.
- Radionuclide deposition from current operations as well as past DOE activities may

occur, especially with ongoing D&D and remedial activities, which may transport contaminants beyond the boundaries of the ORR.

### 3.3.3 Goals

- Obtain data to ascertain if there is any radionuclide contamination in the food crops grown locally due to DOE activities on the ORR.
- Compare TDEC DoR-OR's food crops sampling against results from DOE's food crops sampling program.

### 3.3.4 Scope

The scope of this project was to determine, by sampling and analyzing food crops from gardens, farms, dairies, and other sources within a five-mile radius of the ORR, whether radionuclide contamination extends beyond the boundary of the ORR and was impacting local food crops.

### 3.3.5 Methods, Materials, Metrics

As available, food crops, hay, and milk samples were collected yearly within five miles of the ORR and at background locations greater than this distance to establish background levels (Figure 3.3.1). Sample amounts collected depended on laboratory requirements and available amounts of sample material. Samples were shipped to a laboratory for radiological analysis. Samples were compared with background levels of similar samples as well as the results from similar sampling by DOE. The results of the radiological analysis of the DOE samples are published annually in the ASER, with hay and vegetable samples collected annually and cow milk samples collected from Maryville and Claxton as recently as 2016.

Vegetable, hay, and milk samples were collected by TDEC DoR-OR staff both in 2020 (July and September) and in 2021 (June). Samples were shipped to the Tennessee Department of Health (TDH) laboratory for radiological analysis.

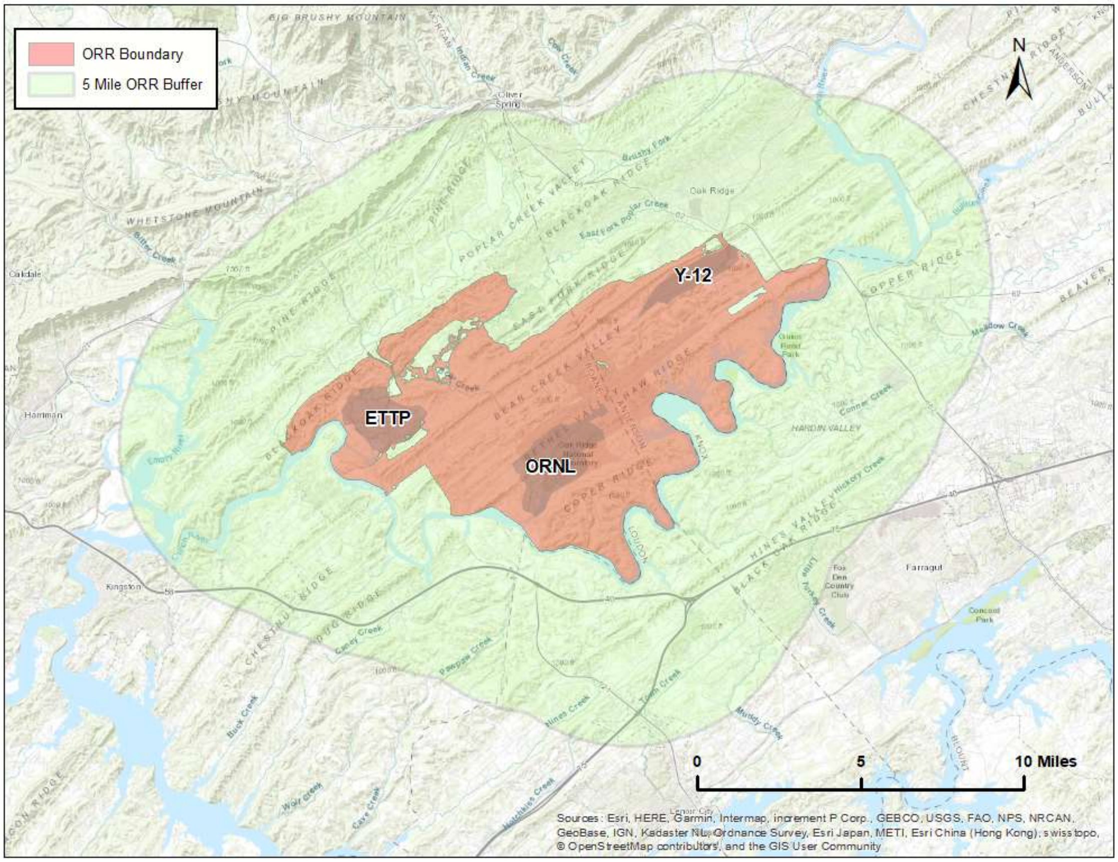


**Figure 3.3.1 Map of the five-mile radius around the ORR**

## 3.1.6 Deviations from the Plan

Due to extenuating circumstances, only background milk, hay, tomatoes, and leafy greens samples were collected during July 2020. An additional two fruiting crop samples (pumpkin and squash) were collected in September 2020 from a garden in the central section of Oak Ridge. An additional twelve samples were collected in the next growing year (June 2021). One of these samples was accidentally destroyed due to a laboratory instrument malfunction. Only gross alpha, gross beta, and gamma analysis results were available at the time of the report for the ten vegetable and hay samples from June 2021, not strontium-90 (Sr-90) and isotopic uranium results. The 2020 samples have these results available, as do both FY 2021 milk samples. The missing Sr-90 and isotopic uranium results from the June 2021 samples will be discussed in the next EMR. Uranium metals analysis was only done for the first six samples, collected in 2020. As uranium metal has not been detected in any samples since the inception of the project, and this project is primarily about radiological contaminants, only isotopic uranium analysis was completed for the subsequent samples. Also, the DOE data for all years was not yet supplied by the time this report was written, so the 2019 ASER food crop results were used for comparison.

### 3.3.7 Results and Analysis

The results of the Food Crops sampling completed by TDEC DoR-OR in Fiscal Year 2021 (FY 2021, July 2020 – June 2021) are shown in Table 3.3.1 and Table 3.3.2, and cover parts of two calendar years as well as two growing seasons. The first six samples were collected in July and September 2020 and the last eleven samples were collected in June 2021. The Sr-90 and isotopic uranium data for the vegetable and hay samples are not yet available for the June 2021 samples (FY 2021) and will be discussed with the FY 2022 (July 2021 – June 2022) sampling results in next year's report. While these samples were collected during different fiscal years, they were collected during the same growing season (summer 2021) and can be compared that way as well.

**Vegetables and Hay**

The available vegetation data (from vegetable and hay samples) for FY 2021 is shown in Table 3.3.1. Results shown in gray text rather than black were below the sample specific minimum detectable amount for that analysis. Locations with green shaded cells were background or reference locations from greater than five miles from the ORR. The samples for which an analyte has not yet received results have cells shaded in light yellow and the results will be included in the next Environmental Monitoring Report. The results of the gamma analyses with no values and the cells shaded gray, had no reported results for that analyte.

Interestingly, the samples from 2020 tended to have much higher gross alpha, gross beta, and potassium-40 (K-40) results in comparison with the samples collected in June 2021. This was still the case at reference locations well over five miles from the Oak Ridge Reservation. Some amount of isotopic uranium (U-234, U-235, U-238), gamma emitting daughter products, and K-40 are naturally occurring in soils and thus not unexpected, though their concentrations were much more than the 2019 TDEC DoR-OR sample results. Despite the increase in isotopic uranium concentrations, the amount of isotopic uranium in the 2020 vegetable samples remains negligible when compared to the IAEA food products standard of 2.7 pCi/g for uranium-235. There are no known FDA isotopic uranium limits for comparison.

Beryllium-7 (Be-7) is a naturally occurring cosmogenic radionuclide and is also not unusual. The one available strontium-90 (Sr-90) result above detection limits was from a background location and was at similar levels to the other background Sr-90 results. While the available isotopic uranium results were mostly above detection limits, similar though lower levels were seen at the reference location. Higher levels of isotopic uranium were seen at locations with higher levels of gross alpha and may be due to fertilizer use. This fits with the higher levels of K-40 (a beta and gamma emitter) seen at these locations, as higher levels of K-40 are seen with increased amounts of potassium, in NPK (nitrogen, phosphorus, and potassium) fertilizer. Uranium levels in soils can even be increased with fertilizer use, as uranium and thorium are often concentrated during the manufacture of fertilizers from the levels normally found in the phosphate rocks used to make fertilizer. This can lead to higher gross alpha levels, levels of isotopic uranium, and levels of daughter products emitting gamma radiation (World Nuclear Association, 2020; ORAU 2021). It appears that hay (grasses) and leafy greens may naturally bioaccumulate K-40, as it was seen in higher levels in those samples, even when no fertilizer was likely to have been applied.

The most recent DOE Food Crop ASER data is from 2019. The hay and vegetable data from the 2019 ASER converted to the same units used for Table 3.3.1, are shown in Table 3.3.2. Only data with results above detection limits were shown in the 2019 ASER, as opposed to shown in gray in Table 3.3.1. Detection limits are likely not the same between sampling projects as different laboratories were used. While some of the FY 2021 TDEC DoR-OR gross alpha results are similar to the 2019 DOE Food Crops results, a number of the gross alpha results from TDEC DoR-OR samples were higher, possibly due to fertilizer use. The same was true with gross beta and K-40 results. The one set of results that did not match well, were those for isotopic uranium. Even the lowest of the TDEC DoR-OR results for isotopic uranium were an order of magnitude higher than those seen in the DOE results. However, only five of the fifteen FY 2021 TDEC DoR-OR samples have available isotopic uranium data for comparison and the data from the 2019 (FY 2020) TDEC DoR-OR sampling was more in line with DOE's 2019 vegetable and hay results.

**Table 3.3.1. Results from TDEC FY 2021 vegetable and hay food crops sampling (pCi/g)**

| | | | | gross | gross | isotopic uranium | | | (beta) | gamma | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | Location | Sample | date | alpha | beta | U-234 | U-235 | U-238 | Sr-90 | K-40 | Be-7 | Pb-212 | Pb-214 | Tl-208 |
| 2020 | Reference 1- Niota Farm | hay/grasses | 7/22/2020 | 0.31 | 5.6 | 0.028 | 0.003 | 0.0187 | 0.060 | 5.5 | 3.11 | 0.142 | | |
| 2020 | Reference 1- Niota Farm | leafy greens | 7/22/2020 | 1.48 | 20.0 | 0.057 | .007 | 0.049 | 0.042 | 23.5 | 4.1 | | | |
| 2020 | Reference 1- Niota Farm | fruiting- tomato | 7/22/2020 | 1.65 | 30.7 | 0.057 | 0.016 | 0.054 | 0.055 | 41.5 | | 0.4 | | 0.29 |
| 2020 | Mid Oak Ridge Garden | fruiting- pumpkin | 9/19/2020 | 1.07 | 20.0 | 0.088 | 0.014 | 0.08 | 0.022 | 28.1 | | | | |
| 2020 | Mid Oak Ridge Garden | fruiting- squash | 9/19/2020 | 1.10 | 24.2 | 0.099 | 0.018 | 0.08 | 0.008 | 30.8 | | | | |
| 2021 | Field east of ORNL | hay/grasses | 6/7/2021 | 0.002 | 5.2 | | | | | 13.8 | 5.6 | | 0.29 | |
| 2021 | Oak Ridge UT Arboretum Field | hay/grasses | 6/7/2021 | 0.07 | 4.2 | | | | | 12.9 | 5.3 | | | |
| 2021 | Oak Ridge Scarboro Field | hay/grasses | 6/7/2021 | -0.16 | 2.4 | | | | | 9.8 | 6.4 | | 0.27 | |
| 2021 | Reference 4- Clinton Farm | hay/grasses | 6/7/2021 | -1.2 | 2.3 | | | | | 16.3 | 5.8 | | | |
| 2021 | ETTP area Field | hay/grasses | 6/9/2021 | -0.14 | 6.1 | | | | | 15.3 | 7.6 | | | |
| 2021 | Oak Ridge Scarboro Garden | greens- turnip | 6/7/2021 | 0.2 | 6.8 | | | | | 10.0 | 0.62 | | | |
| 2021 | Reference 5- Clinton Garden | greens- turnip | 6/7/2021 | 0.32 | 6.0 | | | | | 7.6 | | | | |
| 2021 | Reference 5- Clinton Garden | roots- turnip | 6/7/2021 | 0.28 | 2.1 | | | | | 3.69 | | 0.03 | | |
| 2021 | East Oak Ridge Garden | fruiting- squash | 6/24/2021 | 0.04 | 1.3 | | | | | 1.95 | | | 0.028 | |
| 2021 | East Oak Ridge Garden | fruiting- cucumber | 6/24/2021 | 0.09 | 1.3 | | | | | 2.09 | | | | |

**Table 3.3.2 DOE Food Crop Hay and Vegetable 2019 Data (pCi/g)**

| | gross alpha | gross beta | gamma | | U-234 | U-235 | U-238 |
|---|---|---|---|---|---|---|---|
| | | | Be-7 | K-40 | | | |
| E ORNL hay May | | 7.84 | | **11.6** | 0.0047 | | |
| E ORNL hay June | 0.16 | **12.4** | | | | | 0.0027 |
| N of Y-12 turnip | 0.128 | 5.1 | | 8.3 | 0.0073 | 0.0019 | 0.0079 |
| S of ORNL turnip | | 1.3 | | 1.8 | 0.0025 | | |
| W of ETTP turnip | | 0.7 | | 2.1 | 0.0033 | | |
| Reference turnip | | 1.1 | | | | | |
| N of Y-12 greens | | 3.5 | | 5.3 | 0.0030 | | 0.0018 |
| S of ORNL greens | | 3.9 | | 6.3 | | | 0.0028 |
| E of ORNL greens | | 3.8 | | 5.5 | 0.0088 | | 0.0091 |
| W of ETTP greens | 0.15 | 2.4 | 2.1 | 3.5 | 0.0210 | 0.0015 | 0.018 |
| Reference greens | **0.18** | 2.0 | 2.8 | 4.7 | **0.0320** | **0.0036** | **0.032** |
| N of Y-12 tomato | 0.022 | 2.3 | | 2.0 | | | |
| E of Y-12 tomato | 0.033 | 1.7 | | | 0.0059 | | |
| S of ORNL tomato | | 2.0 | | 2.3 | | | |
| E of ORNL tomato | 0.043 | 1.6 | | | 0.0036 | | |
| W of ETTP tomato | | 1.0 | | | 0.0030 | | |
| Reference tomato | 0.134 | 1.8 | | | | 0.0022 | |

**Milk**

The available milk data for FY 2021 (July 2020 – June 2021) is shown in Table 3.3.3. Both samples are from reference locations well over five miles from the Oak Ridge Reservation. No sampling locations were found in FY 2021 within five miles of the Oak Ridge Reservation, especially no active dairies. The 2020 milk sample was cow milk from a commercial dairy. The June 2021 milk sample was goat milk from a private farm. Again, results shown in gray text rather than black were below the sample specific minimum detectable amount for that analysis. Locations with green shaded cells were background or reference locations from greater than five miles from the ORR. Interestingly, the 2021 reference goat milk sample had a small amount of detected cesium-137 (Cs-137) and had higher levels of K-40 than the cow milk sample. Both TDEC DoR-OR FY 2021 K-40 values were higher than those seen in the 2016 DOE milk sample results. All TDEC DoR-OR and DOE milk sample Sr-90 results were well-below the FDA derived intervention limit of 4400 pCi/L for Sr-90 in milk, and even below detection limits. Analysis from more milk samples and especially goat milk samples would be helpful for more meaningful comparisons. The only results from DOE's 2016 milk sampling program that were above detection limits were for K-40 and are shown in Table 3.3.4, though the 2019 ASER stated that analysis was done for gamma emitters and Sr-90.

**Table 3.3.3. Results from TDEC FY2021 food crops milk sampling (pCi/L)**

| | | | | isotopic uranium | | | | | gamma | |
|---|---|---|---|---|---|---|---|---|---|---|
| year | Location | Sample | date | U-234 | U-235 | U-238 | Sr-90 | Tritium | K-40 | Cs-137 |
| 2020 | Reference 3- Loundon Co. Dairy | Cow Milk | 7/22/2020 | * | * | * | 0.67 | ** | 1420 | |
| 2021 | Reference 4- Clinton Farm | Goat Milk composite | 6/13/2021 | 0.87 | 0.51 | 0.52 | 0.07 | 110 | 1730 | 9.6 |

* analysis failed ** sample not analyzed for tritium

**Table 3.3.4. Results of DOE's milk sampling program from 2016 (pCi/L)**

| | Claxton | | Maryville (reference) | |
|---|---|---|---|---|
| | Mean | Maximum | Mean | Maximum |
| Potassium-40 | 1330 | 1350 | 1325 | 1360 |

Uranium metal was not detected in any TDEC DoR-OR 2019 and 2020 samples (vegetable, hay, and milk).

### 3.3.8 Conclusions

The TDEC DoR-OR Food Crops project collects vegetable, hay, and milk samples within five miles of the ORR as well as at background locations greater than this distance to establish background levels. The samples were analyzed for radiological contaminants. In addition, samples were also compared with the results from similar sampling by DOE in 2016 (milk) and 2019 (vegetables and hay) (ASER, 2017; ASER 2020). As noted, analysis from more milk samples and especially goat milk samples would be helpful for more meaningful comparisons. More vegetable sampling would also be helpful for comparison. Overall, the TDEC DoR-OR FY 2021 vegetable, hay, and milk sampling results do not indicate that DOE ORR activities are significantly impacting radionuclide concentrations in food crops in the areas surrounding the ORR.

### 3.3.9 Recommendations

The TDEC DoR-OR food crop project has had a limited number samples analyzed, so interpretation of results should be done with caution. TDEC DoR-OR recommends that additional food crops sampling be conducted in order to generate a larger dataset to identify any trends in radionuclide uptake that may be present in the vicinity of the ORR and for comparison to historical DOE data and contaminant limits.

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# 4.0 GROUNDWATER MONITORING

## 4.1 OFFSITE (BEAR CREEK VALLEY AND ETTP) GROUNDWATER

### 4.1.1 Background

The offsite groundwater monitoring project has focused on sampling of groundwater wells downgradient of DOE's Oak Ridge Reservation (ORR) for multiple years. Groundwater samples are taken to help identify potential exit pathways and potential anthropogenic impacts to groundwater, which may impact individuals living downgradient of the ORR. The original planned sampling for FY21was severely curtailed by the onset the SARS Cov2 Pandemic and significant associated work restrictions. Instead of 20 samples that were planned for collection during this POP, only four locations were visited and co sampled with DOE. It is intended that the scope proposed in the FY21 EMP will be re-engaged following the SARS Cov2 Pandemic restrictions.

### 4.1.2 Problem Statements

Delineation of the nature and extent of groundwater contamination is incomplete in most areas of the ORR (DOE, 2018c). It is necessary to monitor offsite groundwater for potential migration, until plume delineation and containment across the ORR is complete.

### 4.1.3 Goals

Collect offsite groundwater samples downgradient of the site to detect and evaluate potential legacy contaminant migration and establish a current baseline to facilitate the assessment of current groundwater quality in this area. The data from this Project is to be used to assist the remedial decision-making process as defined by the ORR FFA.

### 4.1.4 Scope

The original planned actions of this project were:

- Collect groundwater samples from residential groundwater wells or springs at 20 locations:
  - One phase from August to November 2020
  - A second phase from March to April 2021
- Evaluate the sample data for potential contaminants of concern (COC) and general water chemistry.

- Use graphing and mapping technology to determine possible trends between the three sampling areas.

### 4.1.5 Methods, Materials, Metrics

Groundwater samples were planned to be collected from 20 locations; QA/QC samples were planned to be collected from at least 10%, (total of two), of those locations. Residential well groundwater samples are collected from an outside tap located as close to the well as possible, and ideally, before water passes through filtration and water softener systems. Wells that were not in use and have no viable dedicated pump system can be sampled by peristaltic or bladder-pump. Springs were sampled using a dipper or peristaltic pump in accordance with internal TDEC DoR-OR standard operating procedures.

The wells sampled by TDEC DoR-OR for this report were co-sampled with DOE contractors. The field parameters that were measured include: temperature (°C), electrical conductivity (µS/cm), pH (SU), oxidation reduction potential millivolts (mV), dissolved oxygen (mg/L), and turbidity (NTU). Wells were purged until, at a minimum, the volume of water stored in the pressure tank or other water storage container had been removed and parameters became stable. Field parameter stabilization is defined as four consecutive readings presented in Table 4.1.1.

**Table 4.1.1: Water Quality Indicator Parameters**

| Water Quality Indicator Parameters | | |
|---|---|---|
| **Measurement (units)** | **Normal Range** | **Acceptable Variability[1]** |
| Temperature (°C) | 10 to 18 | ± 10% |
| pH (SU) | 4.6 to 8.5 | ± 0.1 |
| Specific Conductivity (µS/cm) | 10 to 8,000 | ± 5% |
| Turbidity (NTU) | variable | ± 10% |
| ORP[Eh](mV) | variable | ± 10 mv |

**[1]Acceptable variability over four consecutive readings.**

**°C- Degrees Celsius**

**µS/cm- MicroSiemens per centimeter**

**mV- Millivolt**

**NTU- Nephelometric Turbidity Unit**

**SU- Standard Units**

**ORP- Oxidation Reduction Potential**

**Eh- Reduction Potential**

Samples were sent to the Tennessee Department of Health – Nashville Environmental Laboratory (TDH-NEL) within specified holding times for VOCs, inorganics, and radiochemical analyses. Table 4.1.2 lists the requested analyte list. Although *"the primary groundwater contaminants in the Bear Creek regime are nitrate, trace metals, VOCs, and radionuclides"*, the extensiveness of the list is due to deposited waste in EMWMF and other waste burial sites within the valley (DOE, 2017).

**Table 4.1.2: Requested Analyte List**

| | | |
|---|---|---|
| **VOCs** | | |
| EPA 8260 B list for low level detection[1] | | |
| **METALS** | | |
| aluminum | copper | selenium |
| antimony | iron | silver |
| arsenic | lithium | sodium |
| barium | lead | strontium |
| beryllium | magnesium | thallium |
| boron | manganese | uranium |
| cadmium | mercury | vanadium |
| calcium | nickel | zinc |
| chromium | potassium | total hardness, as calcium |
| **INORGANICS** | | |
| calcium carbonate | total dissolved solids | nitrate and nitrite |
| chloride | sulfate | ammonia |
| fluoride | | |
| **RADIONUCLIDES** | | |
| gross alpha | tritium | radium-228 |
| gross beta | gamma | isotopic uranium |
| strontium-89 | technetium-99 | transuranic radionuclides |
| strontium-90 | radium-226 | |

[1] EPA-8260 B- volatile organic compound analyses list: https://www.epa.gov/sites/production/files/2015-12/documents/8260b.pdf

[2] gamma list includes: Ra-226, Pb-210, Pb-212, Pb-214, Tl-206, Tl-208, Bi-212, Bi-214, K-40

Data are typically compared to the NPDWR (EPA, 2009) and NSDWR (EPA, no date) referenced below. When neither of these are available for a certain contaminant, the data are compared to other EPA criteria including Regional Screening Levels (RSLs) (EPA, 2017), Health Advisories (HA); or EPA Preliminary Remediation Goals (PRG). These standards align with Tennessee public water utility standards.

### 4.1.6 Deviations from the Plan

Groundwater samples were planned to be collected from 20 residential wells and springs as described previously. However, due to the onset of the SARS Cov2 pandemic and associated work restrictions only four sampling locations were visited and co sampled with DOE contractors. These sampled locations included two residential wells and two springs and are in BCV and adjacent to ETTP as shown in the map below (Figure 4.1.2).

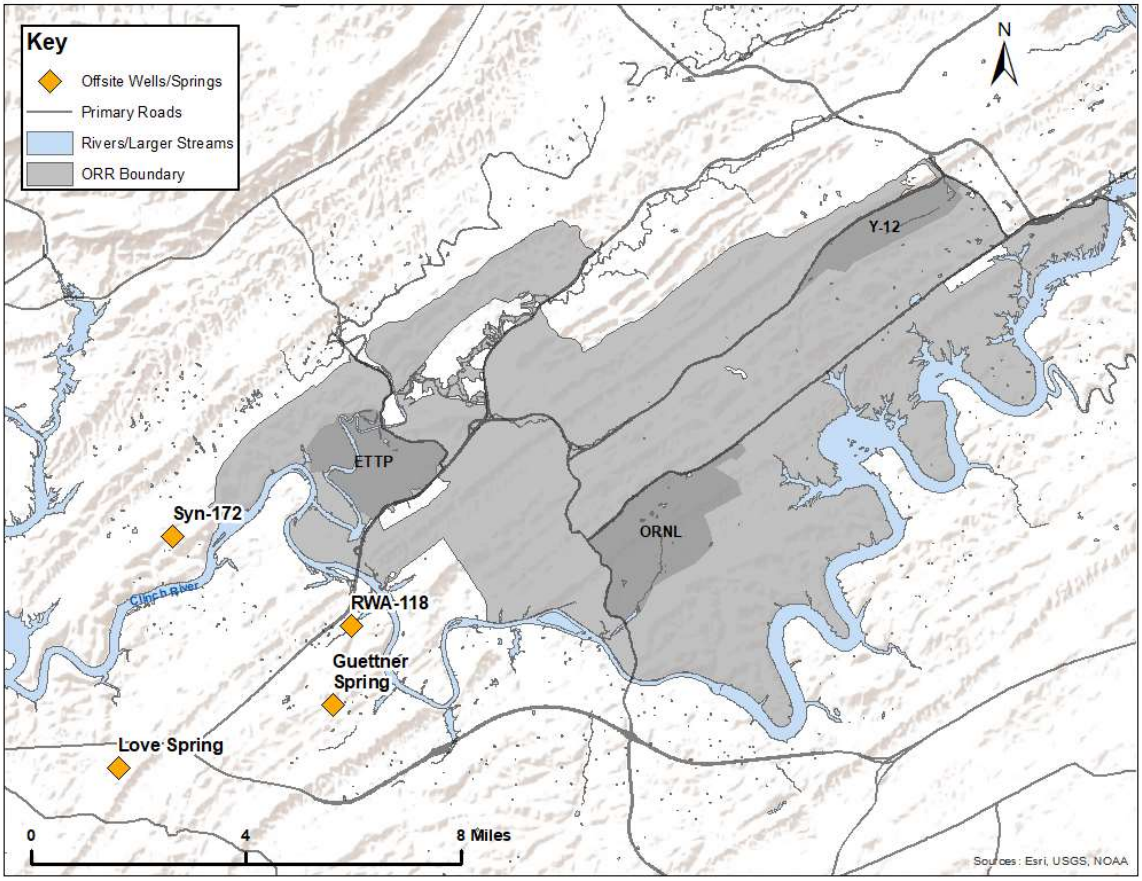


**Figure 4.1.2: Map showing offsite well and spring locations**

## 4.1.7 Results and Analysis

As a significantly revised work outcome resulted from the SARS-Cov2 (Covid) outbreak and increased work restrictions, only wells SYN-172 and RWA-118, Love Spring, and Guettner Spring (Figure 4.1.2) were sampled during this POP. They were co-sampled with DOE contractors.

The results from the data gathered by TDEC was similar to the data collected by DOE during these sampling events.

**Field Parameters**

Temperature, electrical conductivity, pH, oxidation-reduction potential (ORP), dissolved oxygen, and turbidity were measured during the initial purging of the wells. Table 4.1.3

shows the final stable readings taken immediately before collecting samples during each sampling event at the four locations. The only field parameter with a comparison criterion is pH (normal ground water pH= 6.5 to 8.5). All the data are within the EPA SMCL criteria for pH concentrations.

**Table 4.1.3: Field Parameters Measured During Sample Collection**

| Field Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Site Name** | **Sampling Date** | **Temperature (˚C)** | **Electrical Conductivity µS/cm** | **pH (SU)** | **Oxidation-Reduction Potential (mV)** | **Dissolved Oxygen (mg/L)** | **Turbidity (NTU)** |
| **USEPA SMCL** | **N/A** | **N/A** | **N/A** | **6.5-8.5** | **N/A** | **N/A** | |
| **SYN-172** | 2/24/2021 | 13.8 | 420 | 7.32 | 182 | 1.72 | 5 |
| **Guettner Spring** | 3/3/2021 | 13.9 | 153 | 6.93 | 223 | 6.50 | 4 |
| **RWA-118** | 3/4/2021 | 13.2 | 271 | 7.20 | 216 | 6.91 | 1 |
| **Love Spring** | 3/9/2021 | 12.2 | 210 | 6.90 | 200 | 5.91 | 7 |

| | |
|---|---|
| **˚C** | Degrees Celsius |
| **µS/cm** | microSiemens per centimeter |
| **mV** | Millivolt |
| **NTU** | Nephelometric Turbidity Unit |
| **SU** | Standard Unit |
| **DUP** | Duplicate |

**Volatile Organics**

All the volatile organic analytical results were flagged "U" or undetected for samples collected by both DOE and its contractors and TDEC DoR-OR. All the TDEC DoR-OR field trip blanks were reported to contain acetone.

### 4.1.8 Conclusions

The results of the four locations sampled during the SARS-Cov2 restrictions were collected at the same time as samples reported by DOE and its contractors.

In the TDEC DoR-OR results, all the same parameters and their results are present and can be reviewed accordingly. A summary is as follows:

**Guettner Spring:** No VOCs are reported above their respective minimum detection limits (MDL), except for acetone at 7.4 µg/L in the field trip blank. Bismuth-214 ($^{214}Bi$) and lead-214 ($^{214}Pb$) are relatively elevated at 101 and 93 pCi/L respectively. Uranium-series data are low concentration and yielded an activity ratio typical for groundwater fed by percolation water in shallow bedrock settings (Osmond and Cowart, 1993). Radiochemical results are all below all health and advisory criteria. No metals analytical results exceed criteria.

**Residential Well SYN-172:**

VOAs: Acetone at 9.2 µg/L was also present in the field trip blank; no other VOCs are reported above their respective method quantitation limits (MQL). Gross alpha and gross beta (5.23 and 3.4 pCi/L) and uranium-series data are typical of a groundwater bedrock setting. Radium-226 ($^{226}Ra$) and radium-228 ($^{228}Ra$) are both reported at 0.11 and 0.25 pCi/L respectively, below all criteria. Other radiochemical results are also below all health and advisory criteria. No metals analytical results exceed criteria.

**Love Spring:** Two constituents, $^{214}Bi$ and $^{214}Pb$, are relatively elevated at 92 pCi/L and 88 pCi/L respectively. The uranium-series data are such that the water looks like shallow oxygenated percolation-fed groundwater in a shallow surface environment. No VOCs are reported above their respective MDLs, but acetone at 10.2J µg/L is reported in the field trip blank. Radiochemical results are all below all health and advisory criteria. No metals analytical results exceed criteria.

**Residential Well RWA-118:** $^{214}Pb$ is slightly elevated at 36 pCi/L. Gross alpha and gross beta concentrations are (1.95 and 1.5 pCi/L, respectively) and uranium-series data are all typical of a shallow bedrock setting fed by percolation water. No VOCs are reported above their respective MDLs, except acetone at 7.5J µg/L was reported in the field trip blank. Radiochemical results are all below all health and advisory criteria. No metals analytical results exceed criteria.

### 4.1.9 Recommendations

Recommendation for future TDEC DoR-OR groundwater projects include:

- Focus resources to sampling offsite the ORR one valley at a time; compare the results to onsite data results. The first focus should be offsite Bear Creek Valley and ETTP and down the geological strike of Chestnut Ridge as originally planned for 2021.
- Take an in-depth look at the TDEC DoR-OR offsite historical groundwater data in conjunction with DOE offsite data to help guide future groundwater decisions.
- Conduct a data search for each offsite valley and analyze onsite data focusing on the main COCs from each main area (Y-12, ORNL, ETTP), to evaluate impacts to offsite receptors.

### 4.1.10 References

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# 5.0 LANDFILL MONITORING

## 5.1 EMDF SURFACE WATER PARAMETERS

### 5.1.1 Background

The Environmental Management Disposal Facility (EMDF) is proposed for the disposal of low-level radioactive waste (LLRW) and hazardous waste generated by remedial activities on the ORR and will be operated under the authority of CERCLA and DOE. While the EMDF facility will hold no permit from the State of Tennessee, the EMDF is required to comply with DOE orders and substantive portions of ARARs listed in the upcoming CERCLA Record of Decision (ROD).

For radionuclides, the limits on releases from the site are currently based on requirements contained in DOE Order 5400.5 which restricts the release of liquid wastes containing radionuclides to an average concentration equivalent to a dose of 100 mrem/year. The limit for discharges from the site to Bear Creek are based on TDEC 0400-20-11-.16(2) [10 CFR 61.41] which restricts public dose to radioactive material released from LLRW disposal facilities to 25 millirem (mrem) to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public. EPA has deemed this rule to be protective under CERCLA. EPA provides an approximate Effective Dose Equivalent (EDE) of 10 mrem/year to assist with applying this requirement to radiation risk assessment at CERCLA sites. Additional site-specific risk-based discharge limits are currently being developed for discharges to Bear Creek from EMDF following requirements established in the EPA Administrator's Dispute Resolution Decision, dated December 31, 2020.

TDEC DoR-OR's monitoring of groundwater and surface water will assist DOE in their efforts to comply with the requirements stated in the upcoming EMDF ROD and Tennessee General Water Quality Criteria (TDEC 2019). Some surface water monitoring is conducted by DOE using automated multiparameter probes at six flumes which were installed around the EMDF site.

### 5.1.2 Problem Statements

- Contaminants in the proposed waste materials from CERCLA remediation activities will be buried in the EMDF and may leach out and enter the environment.
- Surface water or groundwater may carry these contaminants off site in concentrations or radiological activities above agreed-to limits.
- Only low-level radioactive waste, as defined in TDEC 0400-02-11.03(21) with

radiological concentrations below limits imposed by an expected Waste Acceptance Criteria (WAC), and agreed to by the FFA tri-parties, (DOE, EPA and TDEC), will be approved for disposal in the EMDF. DOE will be accountable for compliance with the WAC.

### 5.1.3 Goals

The goals of the EMDF Monitoring Project are:

- This project will provide assurance through independent monitoring and evaluation of DOE’s data, that collected background or baseline data (temperature, conductivity, pH, and flow) will be useful in protecting the public health and the environment.
- Surface water monitoring will verify that DOE has adequately determined background water quality parameter levels in the surface water by measuring those water quality parameters (temperature, conductivity, pH, and Oxidation Reduction Potential [ORP]).
- Surface water monitoring will act as complementary monitoring and analysis for DOE’s actions.

### 5.1.4 Scope

The scope of the EMDF Monitoring Project included the following:

- TDEC DoR-OR staff members measured water quality parameters in streams at six flume discharge locations: SF-1, SF-2, SF-3, SF-4, SF-5 and SF-6 and spring D10W (Figure 5.1.1). Staff members monitored these locations with the use of a YSI-Professional Plus water quality instrument or equivalent.
- Observations of site conditions and surface water parameter measurements were made twice a week as conditions warranted.

### 5.1.5 Methods, Materials, Metrics

Tasks for this program included monitoring parameters at seven locations, SF-1, SF-2, SF-3, SF-4, SF-5 and SF-6 and spring D10W (Figure 5.1.1). TDEC DoR-OR personnel performed basic monitoring of these locations for temperature, pH, conductivity, dissolved oxygen, and oxidation reduction potential at least twice weekly utilizing a YSI-Professional Plus water quality meter or its equivalent. Calibration and/or a confidence check of this instrument was performed prior to field use.

To ensure DOE utilized best practices to limit possible contaminant migration, on a bi-weekly basis TDEC DoR-OR visited the EMDF site to perform general monitoring of the site. TDEC DoR-OR monitored the streams, noted discharges and water condition, observed the condition of the banks and noted any concerns. Concerns were brought to the attention of DOE/EMDF personnel. Field notes were recorded in a field book and events were reported in a TDEC DoR-OR project monthly report.

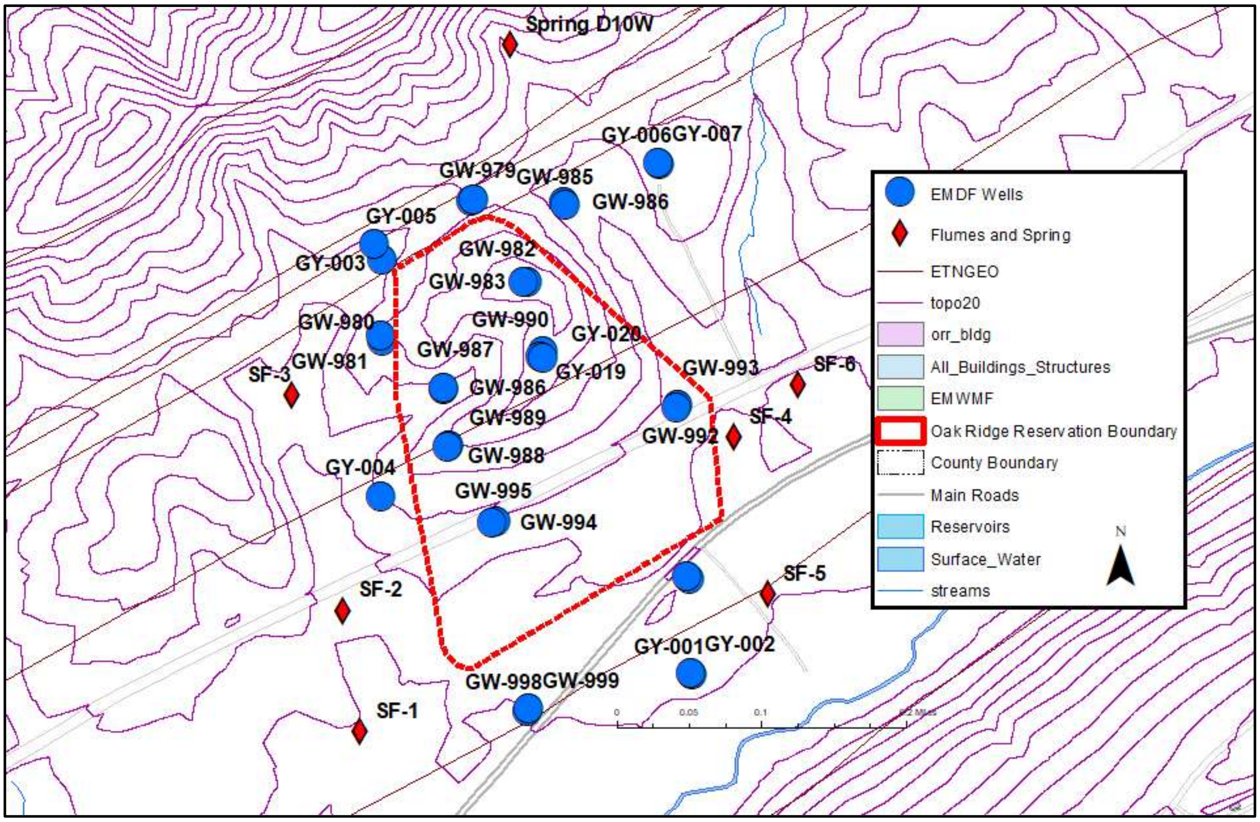



**Figure 5.1.1: Sampling Locations EMDF 2021 Monitoring**

Data collected from these key locations by DoR-OR and DOE were entered into an Excel database for interpretation. Interpretation included construction of tables and graphs illustrating ranges and limits of parameters over the course of the project. Water quality parameters included, temperature, pH, specific conductivity, oxygen reduction potential and dissolved oxygen. Water sampling for analysis by TDEC DoR-OR was conducted. Pertinent water quality criteria from the EPA and TDEC was included on the graphs.

Twice per week, the TDEC DoR-OR project lead performed independent monitoring (check and record water quality parameters) at sites shown on Figure 5.1.1.

Parameter measurements followed *TDEC DoR Quality Assurance Project Plan* (2015) and the *Sampling and Analysis Plan* (2016).

## 5.1.6 Deviations from the Plan

On certain weeks, some of the monitoring events were not completed. This was due to unavoidable schedule changes, changes in priorities, accessibility, or weather.

## 5.1.7 Results and Analysis

Tables 5.1.1 through 5.1.7 contain the monthly statistics for the seven stations measured during FY 2021. The stations are SF-1, SF-2, SF-3, SF-4, SF-5, SF-6, and Spring 10W. The tables contain monthly statistics: maximums, minimums, and averages for each month for each station. The water quality parameters measured were temperature (T), pH, conductivity (Cond), dissolved oxygen (DO), and oxidation reduction potential (ORP). The total number of measurements for each month is listed as 'n' on the table. Some stations were not visited due to accessibility concerns.

Figures 5.1.2 through Figure 5.1.7 illustrate graphically the aforementioned routine water quality parameters measured at the surface water flumes, SF-1 through SF-6, and Spring D10W. These water quality parameters can indicate situations that DOE may need to be aware of during design, building and operation of the EMDF.

All the flumes occasionally do not discharge water after extended periods of no precipitation. However, flumes SF-2, SF-4, SF-5, and SF-6 would have no or little flow for extended periods until a rainfall event. Those 'no flow' or 'not visited' instances are the zero measurements, and since there is no flowing water, no water quality parameters are measured either.

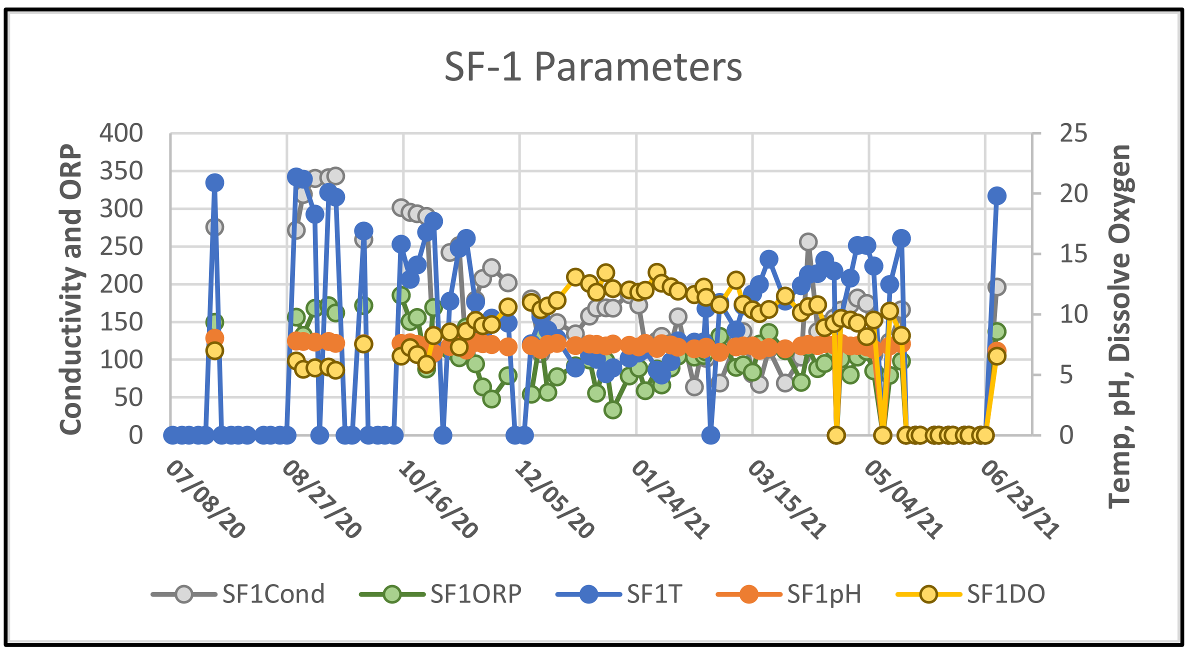



**Figure 5.1.2: SF-1 Water Quality Parameters**

**Table 5.1.1 Monthly Statistics for Flume SF-1**

| | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max T | 20.9 | 21.4 | 21.2 | 17.7 | 16.3 | 9.8 | 7.1 | 10.5 | 14.6 | 15.7 | 19.4 | 19.8 |
| Min T | 20.9 | 21.4 | 16.9 | 12.9 | 8.3 | 5.6 | 5.1 | 5 | 8.7 | 9.7 | 12.5 | 19.8 |
| Ave T | 20.9 | 21.4 | 19.24 | 15.46 | 11.6 | 7.94 | 6.27 | 7.17 | 11.47 | 13.2 | 15.63 | 19.8 |
| Max pH | 8.03 | 7.8 | 7.78 | 7.65 | 7.69 | 7.62 | 7.61 | 7.58 | 7.39 | 7.61 | 7.6 | 6.97 |
| Min pH | 8.03 | 7.8 | 7.6 | 6.81 | 7.07 | 7.10 | 7.33 | 7.16 | 6.87 | 7.4 | 7.11 | 6.97 |
| Ave pH | 8.03 | 7.8 | 7.7 | 7.41 | 7.42 | 7.42 | 7.48 | 7.31 | 7.20 | 7.48 | 7.38 | 6.97 |
| Max Cond | 275.9 | 271.6 | 343.3 | 301.6 | 251.6 | 180.8 | 186.5 | 157 | 137.2 | 256.2 | 196.2 | 196.1 |
| Min Cond | 275.9 | 271.6 | 259 | 108.6 | 109.1 | 108.6 | 118.6 | 63.9 | 67.5 | 103.7 | 107 | 196.1 |
| Ave Cond | 275.9 | 271.6 | 320.58 | 257.7 | 201.96 | 139.3 | 163.01 | 117.79 | 94.29 | 165.04 | 156.98 | 196.1 |
| Max DO | 7 | 6.18 | 7.56 | 8.26 | 10.62 | 13.09 | 13.45 | 13.5 | 12.85 | 10.82 | 10.3 | 6.56 |
| Min DO | 7 | 6.18 | 5.4 | 5.86 | 7.31 | 10.39 | 11.83 | 11.43 | 10.08 | 8.92 | 7.06 | 6.56 |
| Ave DO | 7 | 6.18 | 5.928 | 6.922 | 8.98 | 11.27 | 12.27 | 12.24 | 10.99 | 9.79 | 8.71 | 6.56 |
| Max ORP | 149.5 | 156.2 | 172.1 | 185.6 | 143.7 | 129.9 | 99.9 | 110.3 | 136.3 | 116 | 111 | 137.4 |
| Min ORP | 149.5 | 156.2 | 132.2 | 88 | 48.2 | 54 | 33.8 | 66.5 | 83.7 | 70.4 | 79.7 | 137.4 |
| Ave ORP | 149.5 | 156.2 | 161.26 | 150.00 | 92.09 | 82.02 | 73.46 | 95.6 | 109.59 | 95.99 | 95.73 | 137.4 |
| n | 1 | 1 | 5 | 5 | 6 | 5 | 7 | 7 | 7 | 8 | 6 | 1 |

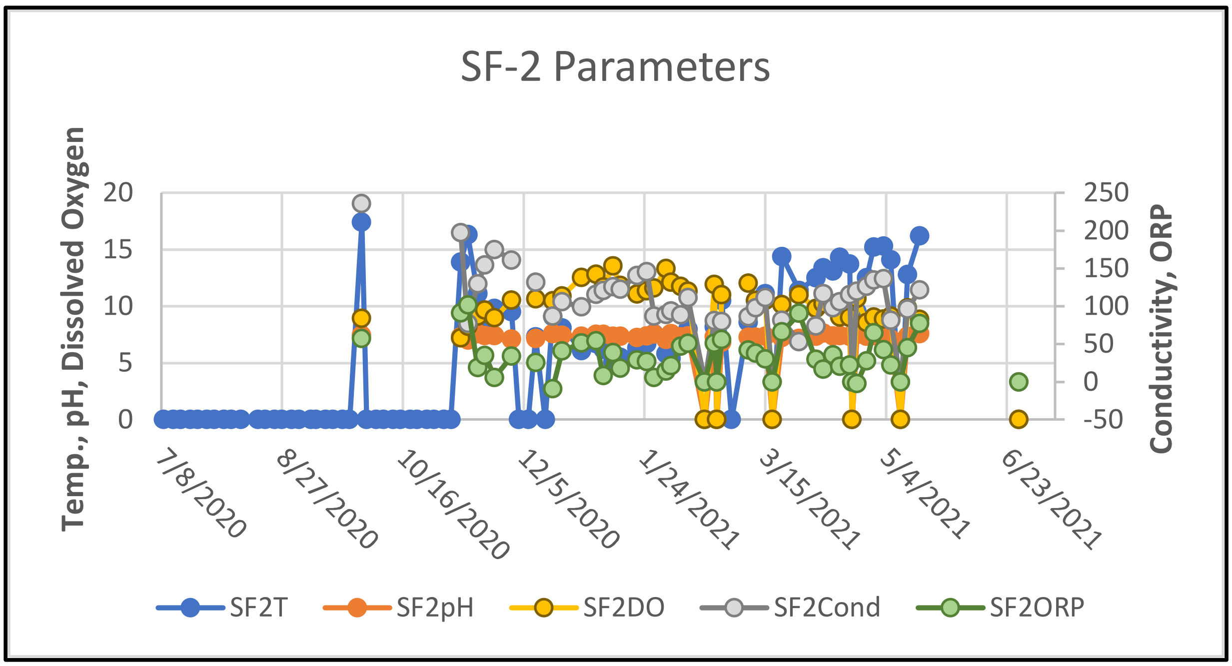



**Figure 5.1.3: SF-2 Water Quality Parameters**

## Table 5.1.2 Monthly Statistics for Flume SF-2

SF-2 Fiscal Year 2021

| | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max T | 0 | 0 | 17.4 | 0 | 16.3 | 9.1 | 7.6 | 8.2 | 14.4 | 15.2 | 19.3 | 0 |
| Min T | 0 | 0 | 17.4 | 0 | 8.5 | 6.1 | 5.1 | 5.4 | 8.6 | 9.5 | 12.8 | 0 |
| Ave T | 0 | 0 | 17.4 | 0 | 11.52 | 7.65 | 6.3 | 6.86 | 11.2 | 13.03 | 15.57 | 0 |
| Max pH | 0 | 0 | 7.46 | 0 | 7.59 | 7.59 | 7.56 | 7.59 | 7.34 | 7.62 | 7.59 | 0 |
| Min pH | 0 | 0 | 7.46 | 0 | 7.01 | 7.18 | 7.24 | 7.06 | 7.17 | 7.33 | 7.09 | 0 |
| Ave pH | 0 | 0 | 7.46 | 0 | 7.31 | 7.40 | 7.42 | 7.32 | 7.26 | 7.42 | 7.36 | 0 |
| Max Cond | 0 | 0 | 235.5 | 0 | 197.4 | 131.8 | 145.5 | 111.6 | 111.2 | 134.7 | 137.2 | 0 |
| Min Cond | 0 | 0 | 235.5 | 0 | 77 | 86.8 | 87 | 81 | 53.4 | 74.1 | 81.4 | 0 |
| Ave Cond | 0 | 0 | 235.5 | 0 | 149.12 | 105.95 | 122.6 | 92.76 | 86.12 | 111.31 | 116.73 | 0 |
| Max DO | 0 | 0 | 8.94 | 0 | 10.56 | 12.55 | 13.55 | 13.33 | 12.05 | 10.68 | 9.88 | 0 |
| Min DO | 0 | 0 | 8.94 | 0 | 7.2 | 10.47 | 11.06 | 11.31 | 10.17 | 8.54 | 8.16 | 0 |
| Ave DO | 0 | 0 | 8.94 | 0 | 8.96 | 11.14 | 11.98 | 12.09 | 10.85 | 9.57 | 8.89 | 0 |
| Max ORP | 0 | 0 | 57.3 | 0 | 101.7 | 51.6 | 54.4 | 51.3 | 90.5 | 65.1 | 94.8 | 0 |
| Min ORP | 0 | 0 | 57.3 | 0 | 5.9 | -9.4 | 5.8 | 14 | 30.2 | -2.2 | 22.1 | 0 |
| Ave ORP | 0 | 0 | 57.3 | 0 | 47.83 | 27.18 | 25.99 | 36.90 | 53.34 | 26.86 | 57.83 | 0 |
| n | 0 | 0 | 1 | 0 | 6 | 4 | 7 | 6 | 7 | 8 | 6 | 0 |

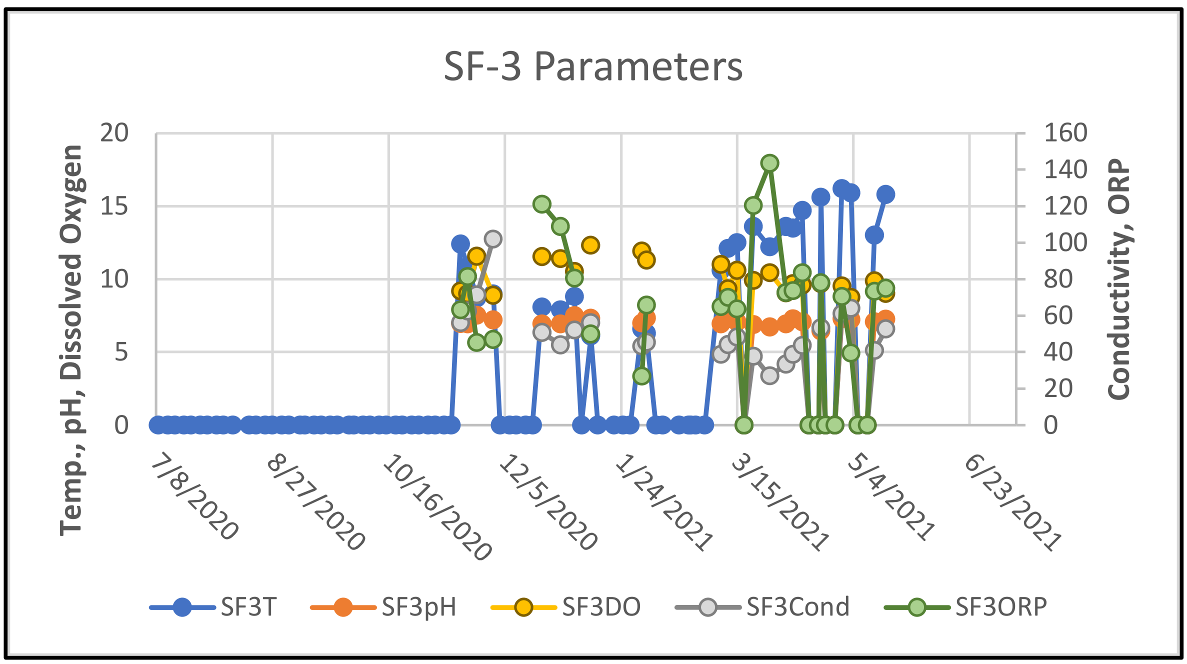



**Figure 5.1.4: SF-3 Water Quality Parameters**

## Table 5.1.3 Monthly Statistics for Flume SF-3

| SF-3 Fiscal Year 2021 | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max T | 0 | 0 | 0 | 0 | 12.4 | 8.1 | 12.4 | 6.6 | 13.6 | 16.2 | 18.8 | 0 |
| Min T | 0 | 0 | 0 | 0 | 8.7 | 7.9 | 8.7 | 6.3 | 10.6 | 13.5 | 13 | 0 |
| Ave T | 0 | 0 | 0 | 0 | 10.25 | 8 | 10.25 | 6.45 | 12.2 | 14.72 | 15.84 | 0 |
| Max pH | 0 | 0 | 0 | 0 | 7.52 | 6.94 | 7.5 | 7.35 | 7.28 | 7.29 | 7.25 | 0 |
| Min pH | 0 | 0 | 0 | 0 | 6.93 | 6.94 | 7.32 | 6.98 | 6.72 | 6.47 | 7.06 | 0 |
| Ave pH | 0 | 0 | 0 | 0 | 7.16 | 6.94 | 7.41 | 7.17 | 6.98 | 7.01 | 7.18 | 0 |
| Max Cond | 0 | 0 | 0 | 0 | 102 | 50.8 | 56.2 | 45.5 | 48.3 | 61 | 64 | 0 |
| Min Cond | 0 | 0 | 0 | 0 | 56.1 | 44 | 52 | 43.3 | 27 | 33.4 | 41 | 0 |
| Ave Cond | 0 | 0 | 0 | 0 | 73 | 47.4 | 54.1 | 44.4 | 39.2 | 46.08 | 55.74 | 0 |
| Max DO | 0 | 0 | 0 | 0 | 11.57 | 11.54 | 12.32 | 11.91 | 11 | 9.69 | 9.89 | 0 |
| Min DO | 0 | 0 | 0 | 0 | 8.88 | 11.41 | 10.52 | 11.31 | 9.36 | 9.05 | 8.36 | 0 |
| Ave DO | 0 | 0 | 0 | 0 | 9.67 | 11.48 | 11.42 | 11.61 | 10.26 | 9.51 | 9.04 | 0 |
| Max ORP | 0 | 0 | 0 | 0 | 81.5 | 120.9 | 80.6 | 65.8 | 143.4 | 83.5 | 77.9 | 0 |
| Min ORP | 0 | 0 | 0 | 0 | 45.2 | 108.7 | 50 | 26.8 | 63.7 | 70.6 | 39.5 | 0 |
| Ave ORP | 0 | 0 | 0 | 0 | 59.2 | 114.8 | 65.3 | 46.3 | 92.5 | 75.72 | 66.3 | 0 |
| n | 0 | 0 | 0 | 0 | 4 | 2 | 2 | 2 | 5 | 5 | 5 | 0 |

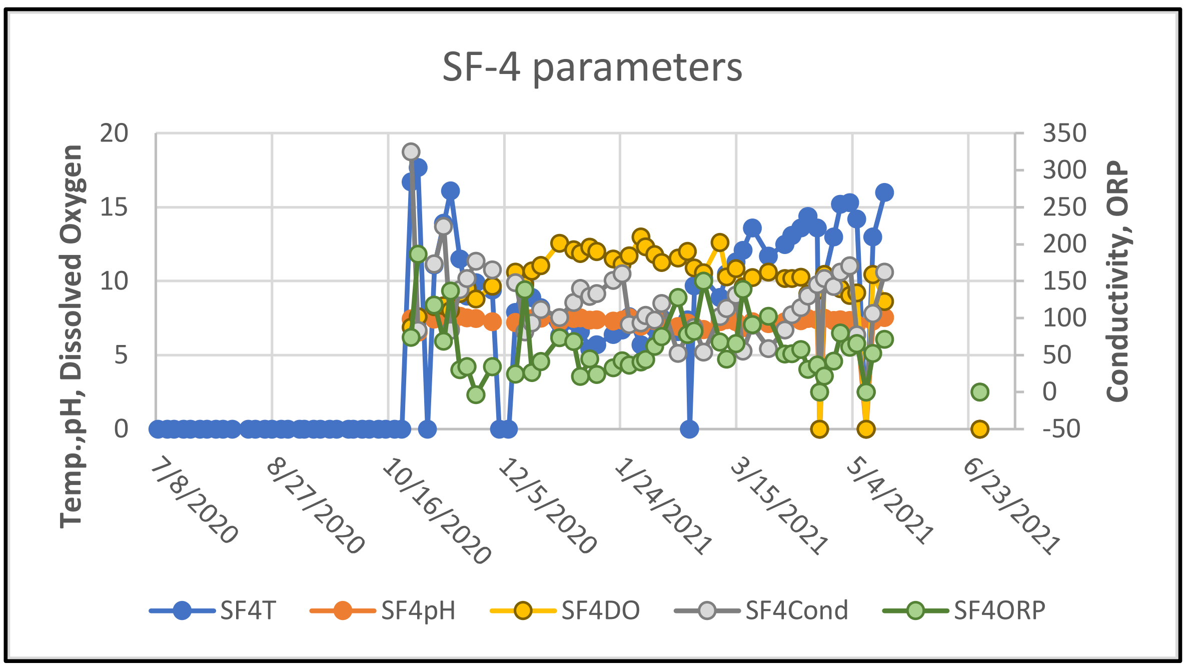



**Figure 5.1.5: SF-4 Water Quality Parameters**

**Table 5.1.4 Monthly Statistics for Flume SF-4**

| SF-4 Fiscal Year 2021 | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max T | 0 | 0 | 0 | 17.7 | 16.1 | 9.9 | 7.6 | 6.6 | 13.6 | 15.2 | 17.7 | 0 |
| Min T | 0 | 0 | 0 | 16.7 | 9 | 6.3 | 5.4 | 6.3 | 10.6 | 10.2 | 13 | 0 |
| Ave T | 0 | 0 | 0 | 17.2 | 11.56 | 8.24 | 6.53 | 6.45 | 12.2 | 13.2 | 15.3 | 0 |
| Max pH | 0 | 0 | 0 | 7.44 | 7.62 | 7.5 | 7.55 | 7.35 | 7.28 | 7.56 | 7.56 | 0 |
| Min pH | 0 | 0 | 0 | 6.55 | 6.82 | 7 | 7.31 | 6.98 | 6.72 | 7.26 | 7.08 | 0 |
| Ave pH | 0 | 0 | 0 | 7.00 | 7.38 | 7.29 | 7.43 | 7.17 | 6.98 | 7.41 | 7.33 | 0 |
| Max Cond | 0 | 0 | 0 | 325.1 | 224 | 148.1 | 160 | 45.5 | 48.3 | 162.2 | 215.9 | 0 |
| Min Cond | 0 | 0 | 0 | 83.7 | 83.8 | 81.2 | 91.3 | 43.3 | 27 | 83.9 | 77.3 | 0 |
| Ave Cond | 0 | 0 | 0 | 204.4 | 159.4 | 107.1 | 132.22 | 44.4 | 39.2 | 129.65 | 150.08 | 0 |
| Max DO | 0 | 0 | 0 | 7.61 | 9.66 | 12.56 | 12.3 | 11.91 | 11 | 10.45 | 10.45 | 0 |
| Min DO | 0 | 0 | 0 | 6.9 | 8.03 | 9.74 | 11.15 | 11.31 | 9.36 | 9.14 | 4.99 | 0 |
| Ave DO | 0 | 0 | 0 | 7.26 | 8.83 | 10.93 | 11.81 | 11.61 | 10.26 | 9.88 | 8.46 | 0 |
| Max ORP | 0 | 0 | 0 | 186.7 | 136.9 | 138.5 | 68.3 | 65.8 | 143.4 | 79.8 | 107.6 | 0 |
| Min ORP | 0 | 0 | 0 | 74.1 | -3.5 | 24.5 | 21.3 | 26.8 | 63.7 | 22 | 52.4 | 0 |
| Ave ORP | 0 | 0 | 0 | 130.4 | 59.96 | 60.92 | 38.56 | 46.3 | 92.5 | 46.51 | 72.62 | 0 |
| n | 0 | 0 | 0 | 2 | 7 | 5 | 7 | 7 | 7 | 8 | 6 | 0 |

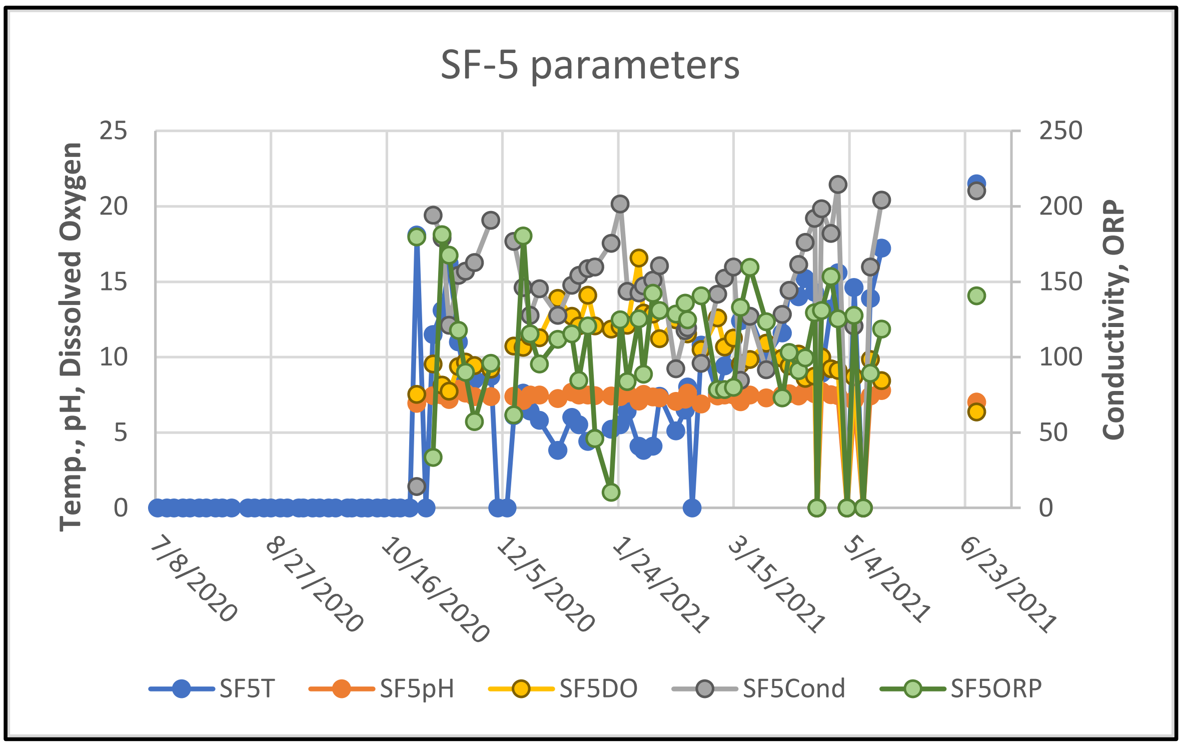



**Figure 5.1.6: SF-5 Water Quality Parameters**

## Table 5.1.5 Monthly Statistics for Flume SF-5

| SF-5 Fiscal Year 2021 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
| Max T | 0 | 0 | 0 | 18.1 | 16.2 | 7.6 | 6.4 | 8 | 12.7 | 15.6 | 19.1 | 21.5 |
| Min T | 0 | 0 | 0 | 18.1 | 8.5 | 3.8 | 4.4 | 3.8 | 7.6 | 8.9 | 13.9 | 21.5 |
| Ave T | 0 | 0 | 0 | 18.1 | 11.09 | 5.94 | 5.37 | 5.57 | 10.59 | 13.4 | 16.22 | 21.5 |
| Max pH | 0 | 0 | 0 | 6.93 | 7.85 | 7.47 | 7.67 | 7.6 | 7.48 | 7.74 | 7.78 | 7 |
| Min pH | 0 | 0 | 0 | 6.93 | 7.18 | 7.1 | 7.37 | 7.05 | 6.88 | 7.43 | 7.12 | 7 |
| Ave pH | 0 | 0 | 0 | 6.93 | 7.47 | 7.33 | 7.49 | 7.30 | 7.29 | 7.55 | 7.44 | 7 |
| Max Cond | 0 | 0 | 0 | 14.18 | 194.1 | 176.7 | 201.4 | 160.6 | 159.8 | 214.4 | 215.3 | 210.2 |
| Min Cond | 0 | 0 | 0 | 14.18 | 121.1 | 127.5 | 143.6 | 92.3 | 84.5 | 128.4 | 120.7 | 210.2 |
| Ave Cond | 0 | 0 | 0 | 14.18 | 165.5429 | 144.62 | 162.9571 | 132.8714 | 121.8 | 174.575 | 181.74 | 210.2 |
| Max DO | 0 | 0 | 0 | 7.51 | 9.65 | 13.89 | 14.1 | 16.57 | 12.59 | 10.2 | 9.85 | 6.35 |
| Min DO | 0 | 0 | 0 | 7.51 | 7.72 | 10.64 | 11.84 | 11.2 | 9.52 | 8.57 | 6.77 | 6.35 |
| Ave DO | 0 | 0 | 0 | 7.51 | 9.01 | 11.58 | 12.41 | 12.86 | 10.76 | 9.40 | 8.31 | 6.35 |
| Max ORP | 0 | 0 | 0 | 179.5 | 181.2 | 180.3 | 124.7 | 142.3 | 159.5 | 153.4 | 127.5 | 140.6 |
| Min ORP | 0 | 0 | 0 | 179.5 | 33.5 | 61.5 | 10.3 | 88.5 | 78.3 | 72.9 | 89.2 | 140.6 |
| Ave ORP | 0 | 0 | 0 | 179.5 | 106.1143 | 112.9 | 83.56 | 125.1429 | 113.3143 | 113.1125 | 115.56 | 140.6 |
| n | 0 | 0 | 0 | 1 | 7 | 5 | 7 | 7 | 7 | 8 | 5 | 1 |

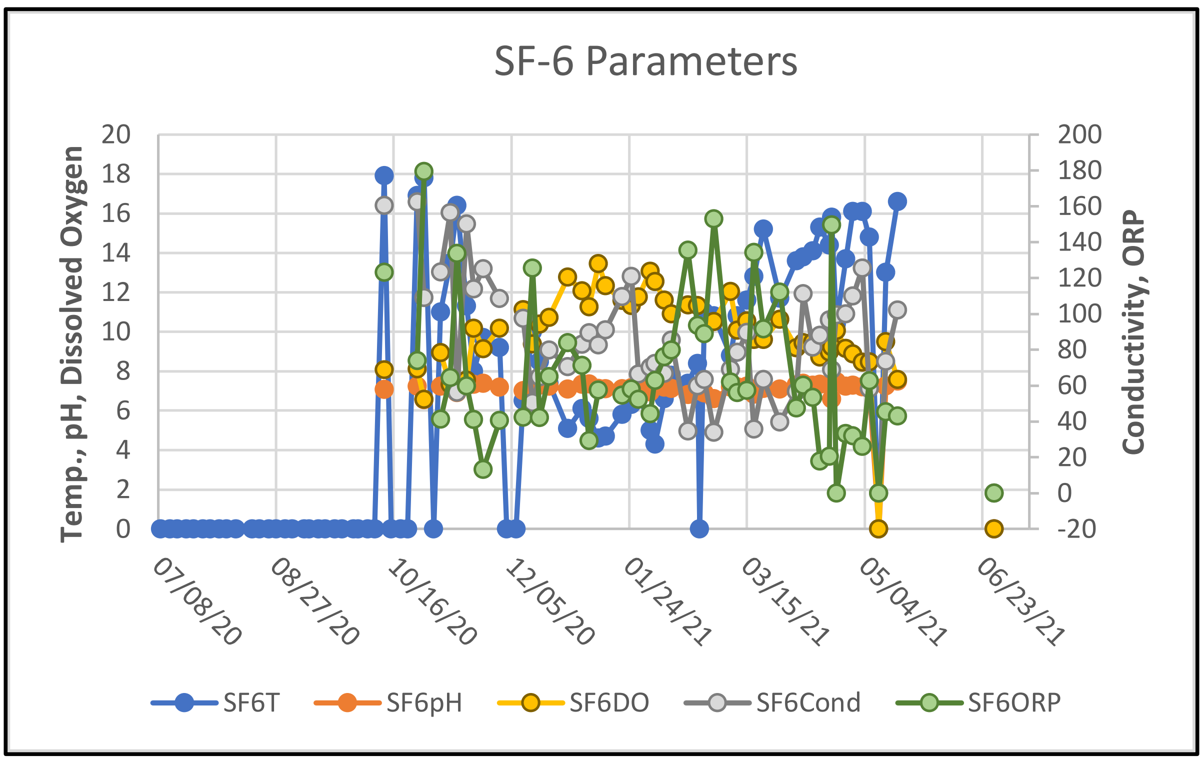



**Figure 5.1.7: SF-6 Water Quality Parameters**

## Table 5.1.6 Monthly Statistics for Flume SF-6

| SF-6 Fiscal Year 2021 | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max T | 0 | 0 | 0 | 17.8 | 16.4 | 10 | 7 | 8.4 | 15.2 | 16.1 | 16.6 | 0 |
| Min T | 0 | 0 | 0 | 16.9 | 8 | 5.1 | 4.6 | 4.3 | 8.8 | 10.4 | 13 | 0 |
| Ave T | 0 | 0 | 0 | 17.35 | 11.3 | 7.5 | 5.73 | 6.58 | 11.67 | 14.13 | 15.38 | 0 |
| Max pH | 0 | 0 | 0 | 7.23 | 7.39 | 7.29 | 7.37 | 7.24 | 7.24 | 7.47 | 7.49 | 0 |
| Min pH | 0 | 0 | 0 | 6.54 | 6.91 | 7.01 | 7.11 | 6.82 | 6.6 | 6.58 | 7.13 | 0 |
| Ave pH | 0 | 0 | 0 | 6.89 | 7.25 | 7.13 | 7.23 | 7.06 | 7.04 | 7.25 | 7.29 | 0 |
| Max Cond | 0 | 0 | 0 | 162.5 | 156.4 | 97.4 | 121 | 85.4 | 89.6 | 111.1 | 125.6 | 0 |
| Min Cond | 0 | 0 | 0 | 108.9 | 56.2 | 50.6 | 66.4 | 34.6 | 33.9 | 56.7 | 58.2 | 0 |
| Ave Cond | 0 | 0 | 0 | 135.7 | 119.0857 | 72.68 | 91.9 | 64.85 | 58.53 | 90.22 | 94.62 | 0 |
| Max DO | 0 | 0 | 0 | 8.12 | 10.19 | 12.76 | 13.45 | 13.08 | 12.04 | 94.3 | 9.5 | 0 |
| Min DO | 0 | 0 | 0 | 6.57 | 6.98 | 9.38 | 11.27 | 10.91 | 9.59 | 8.72 | 7.58 | 0 |
| Ave DO | 0 | 0 | 0 | 7.35 | 8.62 | 10.88 | 11.97 | 11.81 | 10.43 | 18.67 | 8.4 | 0 |
| Max ORP | 0 | 0 | 0 | 179.5 | 133.8 | 125.5 | 71.3 | 135.5 | 152.9 | 149.5 | 62.7 | 0 |
| Min ORP | 0 | 0 | 0 | 73.8 | 13.1 | 42.1 | 29.4 | 44.3 | 56 | -0.1 | 26.1 | 0 |
| Ave ORP | 0 | 0 | 0 | 126.7 | 56.3 | 71.76 | 53.87 | 82.03 | 95.13 | 45.97 | 43.7 | 0 |
| n | 0 | 0 | 0 | 3 | 7 | 5 | 7 | 7 | 7 | 8 | 5 | 0 |

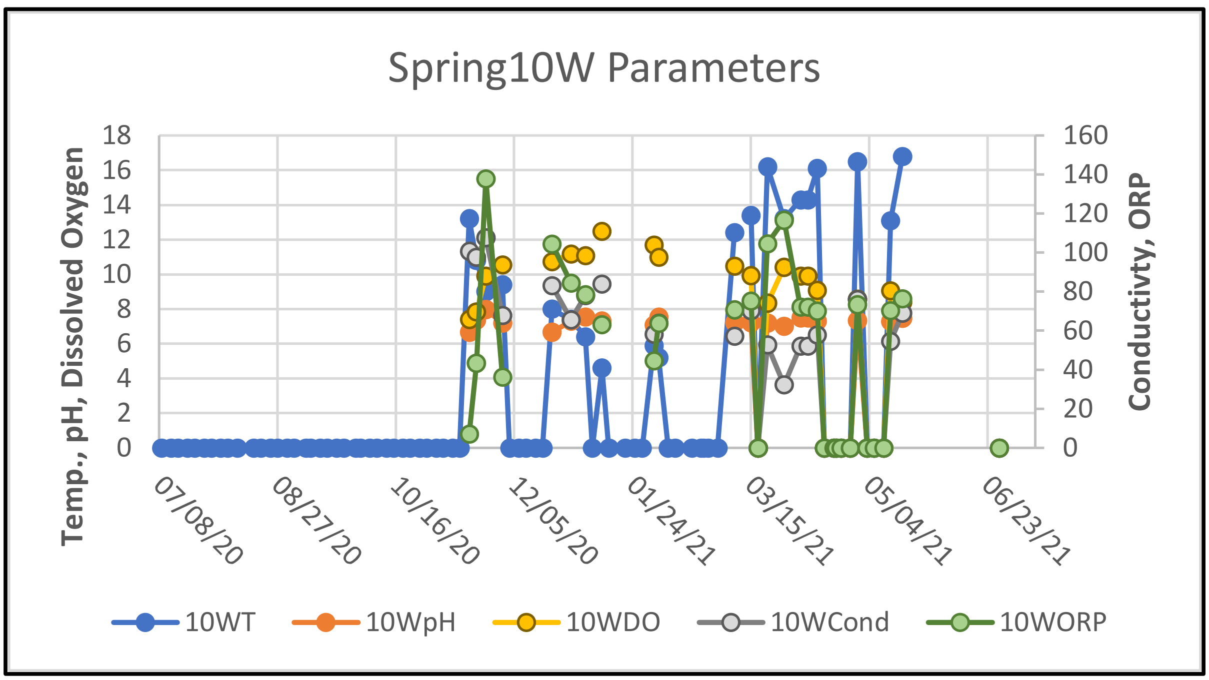



**Figure 5.1.8: Spring 10W Water Quality Parameters**

**Table 5.1.7 Monthly Statistics for Spring 10W**

Spring 10W Fiscal Year 2021

| | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max T | 0 | 0 | 0 | 0 | 13.20 | 8.00 | 6.40 | 8.40 | 16.20 | 16.50 | 19.80 | 0 |
| Min T | 0 | 0 | 0 | 0 | 9.00 | 7.40 | 4.60 | 4.30 | 12.40 | 14.30 | 13.10 | 0 |
| Ave T | 0 | 0 | 0 | 0 | 10.60 | 7.70 | 5.50 | 6.58 | 13.78 | 15.30 | 16.53 | 0 |
| Max pH | 0 | 0 | 0 | 0 | 7.97 | 7.32 | 7.54 | 7.24 | 7.28 | 7.49 | 7.48 | 0 |
| Min pH | 0 | 0 | 0 | 0 | 6.68 | 6.66 | 7.32 | 6.82 | 7.02 | 7.31 | 7.27 | 0 |
| Ave pH | 0 | 0 | 0 | 0 | 7.30 | 6.99 | 7.43 | 7.06 | 7.19 | 7.41 | 7.36 | 0 |
| Max Cond | 0 | 0 | 0 | 0 | 107.60 | 83.10 | 84.00 | 85.40 | 70.36 | 76.10 | 78.60 | 0 |
| Min Cond | 0 | 0 | 0 | 0 | 67.90 | 65.70 | 78.00 | 34.60 | 32.30 | 52.10 | 54.60 | 0 |
| Ave Cond | 0 | 0 | 0 | 0 | 93.45 | 74.40 | 81.00 | 64.85 | 55.89 | 59.55 | 68.40 | 0 |
| Max DO | 0 | 0 | 0 | 0 | 10.54 | 11.17 | 12.47 | 13.08 | 10.48 | 9.90 | 9.06 | 0 |
| Min DO | 0 | 0 | 0 | 0 | 7.40 | 10.73 | 11.08 | 10.91 | 8.34 | 8.58 | 7.20 | 0 |
| Ave DO | 0 | 0 | 0 | 0 | 8.92 | 10.95 | 11.78 | 11.81 | 9.58 | 9.37 | 8.29 | 0 |
| Max ORP | 0 | 0 | 0 | 0 | 137.90 | 104.40 | 78.40 | 135.50 | 116.70 | 73.40 | 108.90 | 0 |
| Min ORP | 0 | 0 | 0 | 0 | 6.98 | 84.40 | 63.20 | 44.30 | 70.70 | 70.10 | 70.30 | 0 |
| Ave ORP | 0 | 0 | 0 | 0 | 56.10 | 94.40 | 70.80 | 82.03 | 88.92 | 71.98 | 83.15 | 0 |
| n | 0 | 0 | 0 | 0 | 4 | 2 | 2 | 2 | 5 | 4 | 4 | 0 |

## 5.1.8 Conclusions

TDEC DoR-OR will use the 2021FY water quality parameter data to assist DOE in determining EMDF specific background surface water quality standards moving forward.

## 5.1.9 Recommendations

TDEC DoR-OR recommends quarterly sampling and spot sampling based on field observations, to perform continuity checks and help determine the health of the tributaries that discharge into Bear Creek. TDEC DoR-OR recommends sampling of surface water at the flumes and the spring as they flow into the Bear Creek tributaries. Sampling at these locations should be conducted on a regular basis where the requested analytical suite is radionuclides metals.

## 5.1.10 References


DOE Order 435.1, 2001, Department of Energy Order 435.1 Radiation Waste Management, Aug. 2001, U.S. Department of Energy Office of Health, Safety and Security

DOE Order 458.1, 2013, Department of Energy Order 458.1 Radiation Protection of the Public and the Environment, Jan. 2013, U.S. Department of Energy Office of Health, Safety and Security

TDEC 2012, Rules of the Tennessee Department of Environment and Conservation. Chap. 0400-20-11, Licensing Requirements for Land Disposal of Radioactive Waste, 2012, Tennessee Department of Environment and Conservation. (2012).

TDEC 2019, Rules of the Tennessee Department of Environment and Conservation. Chap. 0400-40-03, General Water Quality Criteria, Tennessee Department of Environment and Conservation. (2019)

Tennessee Department of Environment and Conservation, Environmental Sampling of the ORR and Environs Quality Assurance Project Plan. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN, 2015.

Tennessee Department of Environment and Conservation, Sampling and Analysis Plan for General Environmental Monitoring of the Oak Ridge Reservation and its Environs, Division of Remediation Oak Ridge (2016)

Tennessee Department of Environment and Conservation Division of Remediation, Oak Ridge Office (DoR OR) 2019 Health and Safety Plan Including Related Policies. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN. January 2020.

Tennessee Department of Environment and Conservation, Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water, Tennessee Department of Environment and Conservation, Division of Water Pollution Control (2018).

United States Environmental Protection Agency. Regional Screening Levels for Chemical Contaminants at Superfund Sites. (March 2020).

## 5.2 EMWMF SURFACE WATER SAMPLING

### 5.2.1 Background

The Environmental Management Waste Management Facility (EMWMF) was constructed for the disposal of low-level radioactive waste (LLRW) and hazardous waste (HW) generated by remedial activities on the Oak Ridge Reservation (ORR) and is operated under the authority of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). While the facility holds no permit from any state agency, it is required to comply with applicable or relevant and appropriate requirements contained in the CERCLA ROD (DOE, 1999) and substantive requirements of DOE directives developed to address responsibilities delegated to the agency by the Atomic Energy Act of 1954.

Currently, the only authorized discharge from EMWMF is contaminated storm water and non-contaminated storm water.[1] As designated by the EMWMF SAP/QAP, contact water is derived from precipitation that falls into an active cell, contacts waste, and collects in the disposal cells above the leachate collection system. The contact water is routinely pumped from the disposal cells to holding ponds and tanks where it is then sampled. Based on DOE's analytical results, it is either treated or released to a storm water sedimentation basin which discharges to a tributary of Bear Creek (BCK) known as North Tributary 5 (NT-5).

For radionuclides, the limits on releases from the holding ponds/tanks to the sedimentation basin are currently based on requirements contained in DOE Order 5400.5 which restricts the release of liquid wastes containing radionuclides to an average concentration equivalent to a dose of 100 mrem/year. The limit for discharges from the sedimentation basin to NT-5 are based on TDEC 0400-20-11-.16(2) [10 CFR 61.41] which restricts public dose to radioactive material released from LLRW disposal facilities to 25 millirem (mrem) to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public. EPA has deemed this rule to be protective under CERCLA. EPA provides an approximate Effective Dose Equivalent (EDE) of 10 mrem/year to assist with applying this requirement to radiation risk assessment at CERCLA sites.[2]

For contaminants other than radionuclides, the point of compliance is the discharge point for the contact water ponds, where Tennessee Ambient Water Quality Criteria for Fish and Wildlife serve as the limits for the releases of contact water to the sediment basin and via the basin to Bear Creek through NT-5. Bear Creek's designated uses currently include recreational, which has not been incorporated into the EMWMF release criteria. This issue must be corrected as required by part of the EPA Administrator's dispute resolution decision, dated December 31, 2020.

For reference:

[1] "Contaminated storm water" is designated "contact water" in the EMWMF Sampling and Analysis Plan (SAP)/Quality Assurance Program Plan (QAPP) [DOE/OR/01-2734&D1/R1]. The EMWMF ROD does not include legal definitions for landfill wastewater, such as those in 40 CFR 445.2(b),(f); 40 CFR 260.10; and TDEC 0400-11-01-.01(2). This omission should be corrected when the ROD is revised in accordance with the EPA Administrator's December 31, 2020, dispute resolution decision.

[2] See Footnote 11 in *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, OSWER No. 9200.4-18, August 22, 1997. Available at https://semspub.epa.gov/work/HQ/176331.pdf.

### 5.2.2 Problem Statements

Contaminated materials from CERCLA remediation activities are buried and continue to be buried in the EMWMF. Over time, associated mobile contaminants have the potential to migrate from the facility into the environment and be carried by ground and surface waters to off-site locations in concentrations above agreed upon limits.

### 5.2.3 Goals

The EMWMF Monitoring Project aims to accomplish the following goals:

- To provide assurance through the independent monitoring efforts and evaluation of DOE's data that operations at EMWMF are protective of public health and the environment and meet the remedial actions objectives specified in the EMWMF ROD.
- To verify that DOE discharges into Bear Creek of contaminated storm water (i.e. storm water that has contacted waste and has not been treated), comply with the established limits and operational requirements.
- To provide independent data on discharges from the underdrain and to evaluate its effectiveness in lowering the groundwater table under the landfill.
- To ensure EMWMF is meeting its operational requirements; discharge data collected by EMWMF is reviewed, quarterly.
- TDEC DoR-OR will collect confirmation samples to ensure best practices are used to limit contaminant migration; site visits were performed to monitor ongoing activities at EMWMF.

### 5.2.4 Scope

The EMWMF Monitoring Project proposed each of the following tasks.

- Staff monitored surface water parameters at the EMWMF-2 (underdrain discharge) and EMWMF-3 (Sediment Basin v-weir discharge) sites at least twice weekly with the use of a YSI-Professional Plus water quality instrument or equivalent. Additional potential locations for parameter measurements were identified at NT5@BCK and BCK 11.54A at the flume (SW-003) (Figure 5.2.1).
- To ensure contaminants from the landfill were not adversely affecting the surrounding environment, water samples were collected on a routine basis from select sites (Table 5.2.1).

- Sediment samples were collected from the sediment basin when the bottom was dry and firm (there is no or little water in the sediment basin). These samples were composited into one sample for analysis.

- Discharge data from EMWMF-2 and EMWMF-3 was measured by DOE on a routine schedule. To ensure EMWMF was meeting its operational requirements TDEC-DoR-OR reviewed the discharge data received from DOE, quarterly.

- TDEC DoR-OR collected confirmation samples as referenced by Table 5.2.1 and Figure 5.2.1.

- Samples were planned to be collected from the weirs at EMWMF-2 and EMWMF-3 on a bi-monthly schedule as referenced by Table 5.2.1.

- EMWMF-4B was to be sampled and analyzed annually as funds permit.

- EMWMF Cell 6W was to be sampled and analyzed annually as funds permit.

Table 5.2.1 and Figure 5.2.1 depict monitoring and sampling locations and sample rationale at the EMWMF.

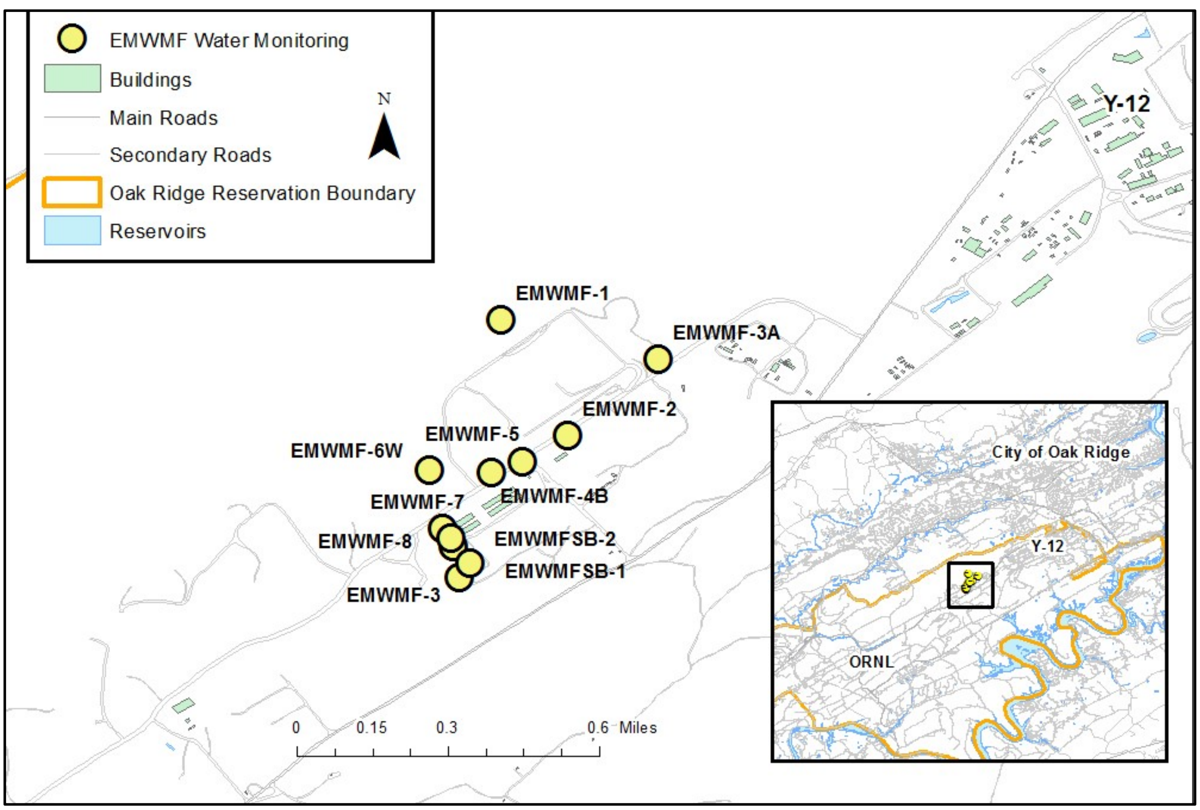



**Figure 5.2.1: Proposed EMWMF Sampling and Monitoring Locations**

**Table 5.2.1: EMWMF Sampling and Monitoring Locations**

| Station | Sample ID | Frequency | Sampling Rationale |
|---|---|---|---|
| **EMWMF Underdrain** | EMWMF-2 | Bi-Monthly | NT-4 discharge below the landfill. The underdrain was installed below Cell 3 and it is theorized that if cells 1,2, and 3 were to leak contaminants, they would first be observed at the underdrain. |
| **Contact Water Ponds/Tanks** | EMWMF-5, EMWMF-7, EMWMF-8 | 1 Location Bi-Monthly | Provides confirmation of contaminant levels being discharged to the sediment basin. |
| **Sediment Basin Effluents (VWEIR)** | EMWMF-3 | Bi-Monthly | Provides confirmation of contaminant levels being discharged from the sediment basin. |
| **Sedimentation Basin Sediment** | EMWMFSB-1, EMWMFSB-2 | One Composite | This location is only sampled when the sediment basin is dry. The results are used to observe the loading of radionuclides in the sediment of the basin. |
| **NT-3 Tributary** | EMWNT-03A or EMWNT-03B | Annually as funds permit | Up-stream surface water location to be used as a baseline. |
| **Cell 6 Drainage** | EMWMF Cell-6W | Annually as funds permit | This location is used as a verification that water collected in Cell 6 (prior to waste placement_ is storm water. |

GW - groundwater

EMWMF - Environmental Management Waste Management Facility

NT - North Tributary

### 5.2.5 Methods, Materials, Metrics

- Twice per week, the project lead performed independent monitoring (check sites and record water quality parameters) at the sites shown on Figure 5.2.1.
- Water samples (from the locations identified in Table 5.2.1 and Figure 5.2.1) were to be collected in accordance with the Project Plan.
- To assess compliance with the radiological limits placed on the outfall of the sedimentation basin, samples were taken from the discharge from the v-weir at the basin (EMWMF-3),
- DOE's analysis focuses on radionuclides that have historically contributed the most to the annual dose quarterly limits for each discharge location.
- TDEC-DoR-OR evaluates the performance of the landfill liner by monitoring parameters and analysis of samples collected from the underdrain (EMWMF-2).
- Sediment samples typically are collected from the sediment basin during the fall when there is less precipitation, and when the bottom of the basin is dry and safe to sample.

- Groundwater and sediment sampling conducted by TDEC follows *TDEC DoR Quality Assurance Project Plan* (2015) and the *Sampling and Analysis Plan* (2016).

The Tennessee Department of Health Laboratory used EPA methods for sample analysis. The requested analytical methods for this project are listed below in Table 5.2.2:

**Table 5.2.2: Laboratory Methods and Analyses**

| Method Designation | Test Name | Analytes |
|---|---|---|
| Method 200.7 | ICP-OES | Metals |
| Method 200.8 | ICP-MS | Metals |
| Method 1631 | Low Level Mercury | Mercury |
| Method 8260B | GC/MS | Volatile Organic Compounds |
| Method 901.1 | Gamma water | Gamma radiation |
| Method ENV-Rad-SOP-401-R.1.3 | Gross Alpha-Beta water by LSC | Gross alpha-beta activity |
| Method 905.0 | Sr-89-90 water | Strontium 89-90 |
| Eichrom Method TCW02 | Technetium-99 water | Technetium-99 |
| Method 906.0 | Tritium water | Tritium |

The results of laboratory analyses were entered into an Excel database for interpretation. Interpretation included construction of tables and graphs illustrating ranges and limits of constituents over the course of the project. Included on the graphs are pertinent water quality criteria from the EPA and TDEC.

### 5.2.6 Deviations from the Plan

On certain weeks during this period of performance, some of the twice weekly monitoring events were not completed. This was due to unavoidable schedule changes, changes in priorities, weather, and coordination of additional requirements associated with a new DOE Radiological Work Plan (RWP) instituted at the end of May 2020 that required a DOE Radiation

Protection Technician be present to measure radiological activity from instruments and workers that may have encountered groundwater or surface water during monitoring at the EMWMF. The RWP requirement ended August 13, 2020, at which point only collected samples were required to be measured prior to leaving the site by the Radiation Protection Technicians at EMWMF.

No sediment samples were collected from the Sediment Basin (proposed as a 1 time sampling event for the POP from sample locations EMWMFSB-1 and EMWMFSB-2) due to the continued presence of water in the basin making collection unsafe.

No TDEC samples were collected from the tributaries (planned as a 1-time sample from EMWNT-03 A or B), from Cell 6 Drainage (planned as EMWMF Cell 6W) or from the contact water ponds at (EMWMF-5, EMWMF-7 or EMWMF-8) during this POP.

Data for these sites was gathered by DOE and was reviewed by TDEC, but TDEC conformation sampling occurred only at EMWMF-2 and EMWMF-3 this FY.

### 5.2.7 Results and Analysis

**DOE Sampling for EMWMF-2 and EMWMF-3**

DOE analyzes samples collected from wells, pipes, streams, ponds, tanks, and air as part of its EMWMF planned monitoring. Most DOE sampling is conducted in monthly, quarterly, annual, and biennial time periods. Of main interest in this report are samples collected for analysis from two discharge point locations, one surface water and one groundwater, designated EMW-VWEIR and EMW-VWUNDRDRAIN, respectively. TDEC DoR-OR uses an alias for these two points, EMW-VWUNDRDRAIN is known in this report as EMWMF-2, (Underdrain), and EMW-VWEIR is known as EMWMF-3 (V-Weir).

DOE's contaminants of concern (COCs) vary for each sampling event depending on the data usage requirements. In addition to these 2 EMWMF-2 and EMWMF-3 locations, fourteen wells are sampled quarterly for "Key COCs": metals, mercury, cyanide, selected anions, pesticides, and isotopic radionuclides consisting of iodine-129, strontium-90, technetium-99, tritium, uranium-233/234, uranium-235/236, and uranium-238. Annually the wells are sampled and analyzed for "Extended COCs" which include volatile organic compounds, benzoic acid, more metals, PCBs, dioxin, and additional radionuclides (carbon-14, cesium-137, chlorine-36, radium-226, and thorium-230). The well samples are analyzed every other year (biennially) for additional analytes – "All COCs": additional volatile and semi volatile compounds, more metals, PCBs, mercury, pesticides, herbicides, cyanide, propylene glycol, methanol, dioxin, and more radioisotopes.

EMWMF-3, EMWNT-03B, EMWNT-05, the Contact Water Ponds 1 through 4, and the Contact Water Tanks A through D follow the same sampling and analysis regimen as above for annual and biennial samplings. EMWMF-2 is collected bi-monthly; EMWNT-03B and EMWNT-05 are collected quarterly for Key COCs. The Contact Water Ponds, and Contact Water Tanks are analyzed for Key COCs prior to each release. The details of the analytes and the schedule are delineated in the *Sampling and Analysis Plan/Quality Assurance Project Plan for Environmental Monitoring at the Environmental Management Waste Management Facility, Oak Ridge, Tennessee,* DOE/OR/01-2734&D1/R1.

**TDEC DoR-OR EMWMF-2 and EMWMF-3 Parameters Discussion**

Figures 5.2.2 through Figure 5.2.7 illustrate the routine water quality parameters measured at EMWMF-2 and EMWMF-3. These water quality parameters can indicate situations, possibly problems, with the liner or in the case of EMWMF-3 contaminated stormwater that was previously not identified. The parameters measured are pH, specific conductivity, water temperature, and oxidation-reduction potential. In addition, the depth of water leaving the weirs was measured.

Table 5.2.3 contains the monthly statistics for the four stations measured during FY2021. The stations are EMWMF-2, EMWMF-3, BCK 11.54A and NT5@BCK. The table contains monthly statistics: maximums, minimums, and averages for each month for each station. The parameters collected were temperature (T), pH, conductivity (Cond), dissolved oxygen (DO), and oxidation reduction potential (ORP).

Figure 5.2.2 depicts the seasonal changes in all parameters measured from 2012 to the present. This graph shows nine seasonal cycles and the corresponding highs and lows of temperature and conductivity. EMWMF-3 occasionally does not discharge water after extended periods of no precipitation. Those are the zero measurements, and since there is no flowing water, no water quality parameters are measured either. The temperature and conductivity of EMWMF-2 on the graph are muted and delayed in relation to EMWMF-3 parameters. Figure 5.2.3 is a depiction of the last two reporting fiscal year's measurements of conductivity and temperature. In September 2018 there was no flow over the weir in EMWMF-3, so there are no measurements from that time. During the shut-down from April to May 2020, no measurements were taken.

Figures 5.2.4 through Figure 5.2.7 illustrate the routine water quality parameters measured at EMWMF-2 and EMWMF-3 for FY2021.

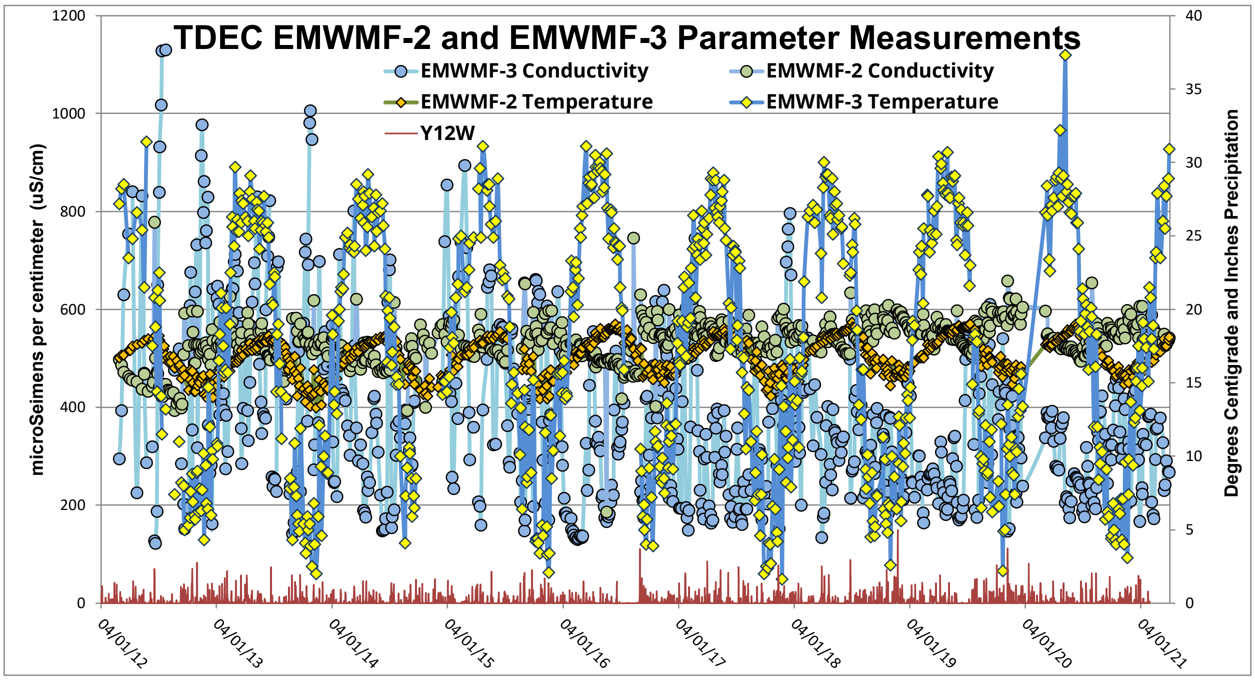



**Figure 5.2.2: TDEC DoR-OR EMWMF-2 and EMWMF-3 Parameter Measurements 2012 To the Present with Precipitation**

## Table 5.2.3 Monthly Parameter Statistics EMWMF-2, EMWMF-3, BCK 11.54A and NT5@BCK Fiscal Year 2021

**EMWMF-3 (VWEIR) Fiscal Year 2021**

| | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Max T** | 32.2 | 37.3 | 27.9 | 20.7 | 18.3 | 9.10 | 7.1 | 9.8 | 17.5 | 21.5 | 27.9 | 30.9 | |
| **Min T** | 27 | 26.5 | 18.5 | 15.9 | 8.4 | 4.40 | 4 | 3.1 | 9.4 | 14.8 | 17.3 | 23.5 | |
| **Ave T** | 29.0 | 28.68 | 23.83 | 19.09 | 12.15 | 5.98 | 5.67 | 6.47 | 13.7125 | 17.41 | 21.47 | 27.3 | |
| **Max pH** | 9.08 | 9.39 | 8.95 | 8.37 | 8.32 | 7.96 | 7.55 | 7.92 | 8.2 | 8.67 | 8.62 | 7.0 | |
| **Min pH** | 7.85 | 8.31 | 7.48 | 7.34 | 7.47 | 7.08 | 7.08 | 7.34 | 7.3 | 8.02 | 6.82 | 6.3 | |
| **Ave pH** | 8.22 | 8.68 | 8.12 | 7.85 | 7.89 | 7.40 | 7.39 | 7.62 | 7.7075 | 8.28 | 7.83 | 6.6 | |
| **Max Cond** | 379 | 261.9 | 264.8 | 318.2 | 423.3 | 391.60 | 457 | 417.6 | 434.2 | 382.2 | 386 | 378.3 | |
| **Min Cond** | 271.8 | 174.5 | 236.7 | 176.2 | 176.2 | 244.60 | 315.7 | 202.9 | 166.7 | 222.6 | 172.5 | 229.7 | |
| **Ave Cond** | 318.23 | 215.28 | 250.89 | 232.92 | 315.08 | 336.70 | 394.27 | 324.41 | 318.95 | 316.57 | 278.89 | 286.4 | |
| **Max DO** | 6.75 | 6.75 | 6.63 | 9.52 | 12.56 | 16.06 | 16.4 | 19.55 | 13.42 | 13.49 | 10.29 | 6.4 | |
| **Min DO** | 4.60 | 5.00 | 5.87 | 7.23 | 8.9 | 12.36 | 12.62 | 12.62 | 9.63 | 9.05 | 5.93 | 5.1 | |
| **Ave DO** | 5.29 | 5.71 | 6.37 | 8.25 | 10.84 | 13.72 | 13.92286 | 15.29 | 11.345 | 11.12 | 8.37 | 5.8 | |
| **Max ORP** | 182.20 | 181.10 | 155.50 | 172.7 | 172.7 | 167.50 | 155.3 | 150.7 | 165.9 | 154.80 | 152.50 | 188.6 | |
| **Min ORP** | 133.10 | 156.60 | 100.90 | 105.6 | 74.6 | 86.00 | 35.8 | 62.3 | 90.7 | 112.20 | 116.90 | 84.8 | |
| **Ave ORP** | 159.14 | 167.29 | 138.23 | 143.52 | 121.21 | 120.47 | 101.89 | 114.43 | 123.1875 | 132.13 | 130.14 | 148.8 | **Total Readings** |
| **n** | 8 | 7 | 8 | 9 | 8 | 6 | 7 | 7 | 8 | 7 | 7 | 7 | 89 |

**EMWMF-2 (Underdrain) Fiscal Year 2021**

| | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Max T** | 19 | 19.1 | 19 | 18.8 | 18.3 | 16.50 | 16.1 | 15.9 | 16.4 | 16.7 | 17.2 | 18.1 | |
| **Min T** | 17.8 | 18.3 | 18.2 | 17.8 | 16.8 | 15.90 | 15.4 | 14.9 | 15.4 | 15.7 | 16.4 | 17.1 | |
| **Ave T** | 18.32 | 18.55 | 18.65 | 18.42 | 17.38 | 16.25 | 15.7 | 15.39 | 15.95 | 16.23 | 16.79 | 17.7 | |
| **Max pH** | 6.8 | 6.67 | 6.8 | 6.73 | 6.77 | 6.99 | 6.98 | 6.93 | 6.93 | 6.93 | 7.15 | 6.7 | |
| **Min pH** | 6.31 | 6.53 | 6.23 | 6.25 | 6.26 | 6.60 | 6.22 | 6.57 | 6.57 | 6.57 | 6.37 | 6.0 | |
| **Ave pH** | 6.56 | 6.61 | 6.45 | 6.43 | 6.43 | 6.73 | 6.72 | 6.80 | 6.7075 | 6.79 | 6.81 | 6.3 | |
| **Max Cond** | 533.2 | 523.6 | 514.3 | 654 | 571.1 | 571.90 | 570.2 | 598 | 605.9 | 605.9 | 588.6 | 549.4 | |
| **Min Cond** | 510.2 | 515.8 | 493.9 | 515.8 | 536.3 | 252.80 | 540.3 | 541.9 | 541.6 | 537.6 | 537.6 | 526.1 | |
| **Ave Cond** | 521.73 | 519.5 | 505.34 | 530.5 | 530.5 | 505.13 | 550.41 | 568.6429 | 568.8125 | 562.31 | 555.89 | 535.5 | |
| **Max DO** | 2.58 | 2.19 | 2.51 | 4.01 | 5.42 | 6.36 | 6.33 | 6.33 | 6.61 | 5.65 | 4.55 | 3.2 | |
| **Min DO** | 1.66 | 1.73 | 1.91 | 1.26 | 3.00 | 3.06 | 4.41 | 4.46 | 2.31 | 2.63 | 2.16 | 1.9 | |
| **Ave DO** | 2.05 | 1.98 | 2.09 | 2.82 | 4.12 | 4.52 | 5.14 | 5.18 | 4.6975 | 3.88 | 3.40 | 2.5 | |
| **Max ORP** | 190.1 | 190.1 | 176.9 | 170.5 | 167.6 | 129.80 | 134.3 | 135.8 | 172.5 | 155.50 | 148.50 | 182.9 | |
| **Min ORP** | 79.5 | 79.5 | 131 | 79.5 | 75.9 | 84.90 | 45.9 | 71.8 | 104.5 | 100.20 | 119.80 | 81.8 | |
| **Ave ORP** | 156.24 | 160.8 | 150.41 | 147.12 | 147.12 | 147.12 | 102.41 | 112.09 | 134.275 | 127.44 | 131.84 | 146.0 | **Total Readings** |
| **n** | 8 | 7 | 8 | 9 | 8 | 6 | 7 | 7 | 8 | 7 | 7 | 7 | 89 |

**BCK 11.54A (SW-003) Fiscal Year 2021**

| | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Max T** | 24.5 | 22.6 | 25.9 | 18.5 | 16.3 | 8.7 | 6.4 | 10.8 | 10.8 | 15.8 | 19.5 | 23.2 | |
| **Min T** | 21.1 | 21 | 16.3 | 12.8 | 7 | 4.6 | 4.5 | 3.9 | 3.9 | 11.7 | 12.8 | 16.1 | |
| **Ave T** | 22.2625 | 21.7 | 20.65 | 16.26667 | 10.9 | 6.416667 | 5.55 | 6.3 | 6.3 | 13.37143 | 15.67143 | 19.6 | |
| **Max pH** | 8.28 | 8.24 | 8.48 | 7.83 | 7.63 | 7.44 | 7.57 | 7.57 | 7.57 | 7.57 | 7.51 | 7.1 | |
| **Min pH** | 8.09 | 7.97 | 7.55 | 7.17 | 7.25 | 7.13 | 7.17 | 7.1 | 7.1 | 7.24 | 6.98 | 6.7 | |
| **Ave pH** | 8.21375 | 8.1525 | 7.79875 | 7.648889 | 7.4657143 | 7.283333 | 7.375 | 7.351429 | 7.351429 | 7.448571 | 7.361429 | 6.9 | |
| **Max Cond** | 636 | 816 | 690 | 790 | 740 | 626.2 | 614.3 | 497.9 | 497.9 | 574.5 | 583.1 | 695.0 | |
| **Min Cond** | 364.4 | 474.6 | 255.8 | 239.9 | 396.2 | 222.5 | 375.5 | 208.6 | 208.6 | 422.4 | 334.5 | 576.8 | |
| **Ave Cond** | 522.4375 | 634.575 | 528.725 | 667.5444 | 623.01429 | 475.4833 | 514.15 | 348.2143 | 348.2143 | 493.6714 | 484.9143 | 622.8 | |
| **Max DO** | 7.93 | 7.89 | 8.61 | 9.07 | 10.96 | 14.36 | 14.49 | 14.2 | 14.2 | 11.61 | 10.77 | 8.6 | |
| **Min DO** | 6.13 | 7.37 | 4.9 | 7.39 | 8.26 | 10.43 | 12.23 | 11.19 | 11.19 | 9.7 | 8.11 | 6.5 | |
| **Ave DO** | 7.1625 | 7.63375 | 6.9175 | 8.363333 | 9.8228571 | 12.185 | 13.435 | 12.86571 | 12.86571 | 10.68 | 9.292857 | 7.7 | |
| **Max ORP** | 178.1 | 189.4 | 169.7 | 174.8 | 170.3 | 171.1 | 161.1 | 142.8 | 142.8 | 160.3 | 133.9 | 180.2 | |
| **Min ORP** | 152.1 | 152.7 | 123.4 | 130.5 | 93.9 | 82.4 | 59.3 | 123 | 123 | 106.9 | 24.4 | 97.8 | |
| **Ave ORP** | 165.125 | 175.6125 | 153.3875 | 160.8222 | 139.01429 | 126.6833 | 116.8333 | 135.4143 | 135.4143 | 135.1714 | 112.6 | 144.2857 | **Total Readings** |
| **n** | 8 | 8 | 8 | 9 | 7 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 86 |

**NT5@BCK Fiscal Year 2021**

| | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Max T** | 26.5 | 25 | 24.1 | 19.6 | 16.8 | 8.5 | 16.1 | 10.5 | 10.5 | 17.2 | 22.4 | 23.6 | |
| **Min T** | 22.4 | 22.3 | 16.7 | 14.5 | 8.5 | 4.2 | 4 | 3.2 | 3.2 | 11.1 | 12.2 | 18.3 | |
| **Ave T** | 24.0375 | 23.375 | 20.2625 | 17.32222 | 11.414286 | 6.15 | 6.916667 | 5.5 | 5.5 | 13.52857 | 17.74286 | 21.3 | |
| **Max pH** | 8.01 | 7.95 | 7.86 | 7.99 | 7.71 | 7.55 | 7.68 | 7.6 | 7.6 | 7.56 | 8.02 | 7.1 | |
| **Min pH** | 7.84 | 7.74 | 6.31 | 7.27 | 7.3 | 7.24 | 6.67 | 7.44 | 7.44 | 7.35 | 7.21 | 6.6 | |
| **Ave pH** | 7.955 | 7.82 | 7.6 | 7.604444 | 7.4871429 | 7.385 | 7.323333 | 7.5375 | 7.5375 | 7.477143 | 7.47 | 6.9 | |
| **Max Cond** | 414.7 | 350.7 | 510.2 | 403.3 | 548.7 | 453.1 | 540.3 | 437.2 | 437.2 | 417.3 | 422.5 | 399.8 | |
| **Min Cond** | 217.2 | 172.1 | 283.3 | 175.5 | 315.1 | 209.6 | 415.8 | 299.4 | 299.4 | 282.7 | 272.9 | 293.8 | |
| **Ave Cond** | 345.925 | 280.9125 | 373.6 | 310.7 | 416.21429 | 378.45 | 460.25 | 355.2 | 355.2 | 362.1143 | 345.925 | 345.3 | |
| **Max DO** | 7.42 | 7.24 | 7.69 | 8.03 | 10.58 | 13.67 | 13.96 | 14.52 | 14.52 | 11.44 | 10.44 | 6.9 | |
| **Min DO** | 5.79 | 6.59 | 2.02 | 6.25 | 7.75 | 10.76 | 4.47 | 12.35 | 12.35 | 7.63 | 6.07 | 5.5 | |
| **Ave DO** | 6.81125 | 7.0175 | 6.205 | 7.033333 | 9.1871429 | 12.17 | 11.78833 | 13.51 | 13.51 | 9.887143 | 8.155714 | 6.1 | |
| **Max ORP** | 184 | 190.8 | 178.1 | 172.5 | 171.1 | 172 | 124.9 | 137 | 137 | 151.5 | 136.3 | 172 | |
| **Min ORP** | 159.1 | 156.3 | 130.8 | 136.5 | 6.9 | 40.1 | 19.9 | 47 | 47 | 6.6 | 48.2 | 98.2 | |
| **Ave ORP** | 172.7875 | 176.475 | 154.375 | 160.8444 | 92.957143 | 83.13333 | 82.7 | 106.8 | 106.8 | 94.48571 | 111.0 | 139.3143 | **Total Readings** |
| **n** | 8 | 8 | 8 | 9 | 7 | 6 | 6 | 4 | 6 | 7 | 7 | 7 | 83 |

| | | |
|---|---|---|
| Max Maximum | T Temperature Centigrade | DO Dissolved Oxygen mg/L |
| Min Minimum | pH Acidity Standard Units | ORP Oxygen Reduction Potential |
| Ave Average | Cond Conductivity micro seiverts | n Total number of readings |

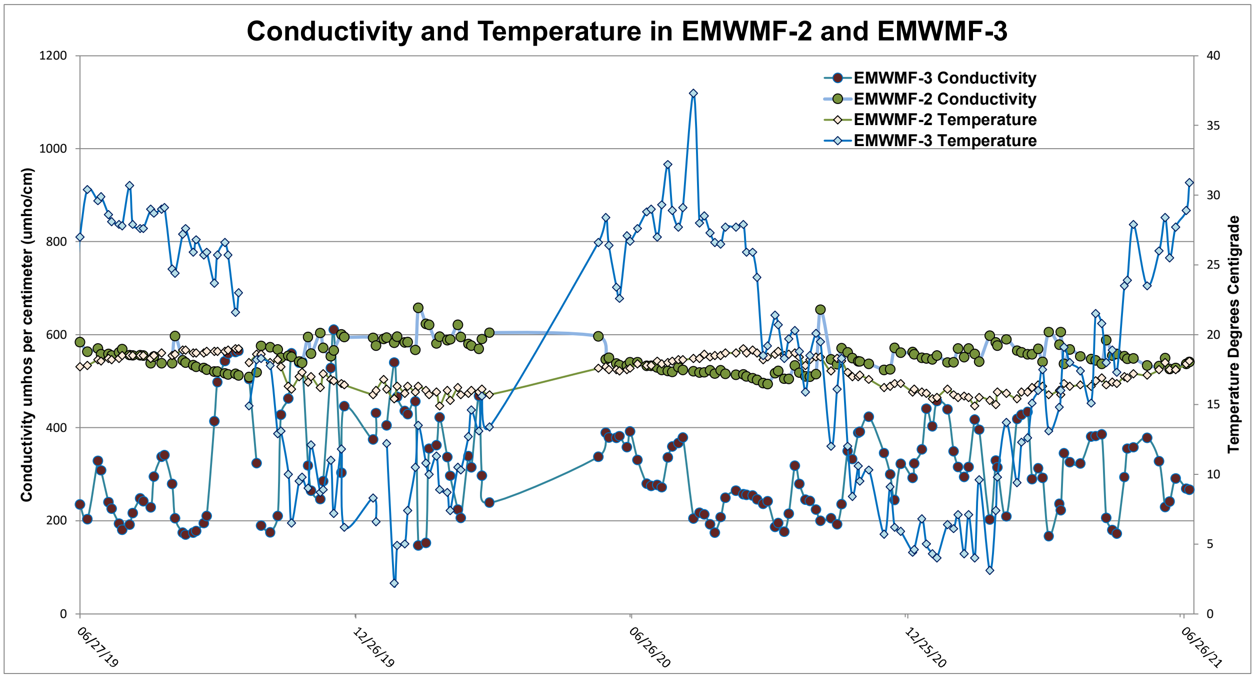



**Figure 5.2.3: FY 2020 and FY 2021 Conductivity and Temperature in EMWMF-2 and EMWMF-3**

Figure 5.2.4 graphs the water temperatures along with precipitation in EMWMF-2 and EMWMF-3 for the 2021 reporting year. The temperatures from EMWMF-2 did not have the same amplitude as EMWMF-3, due mainly to the water in EMWMF-2 being groundwater.

Figure 5.2.5 presents the conductivity measured in both stations and precipitation from the Y-12 West weather station. EMWMF-3 is open to the environment, collects water from different sources, and has a variability that the EMWMF-2 water does not. The seasonal variation in the conductivity of the EMWMF-2 water was seen here.

Figure 5.2.6 graphs pH measurements and precipitation for the reporting years of 2012 to 2021. Seasonal variability was present for both stations with the range of measurements greater in EMWMF-3. This was expected since the water is open to the environment. The spike in pH for both EMWMF-2 and EMWMF-3 on October 31, 2019, was due to a faulty pH probe in the measuring instrument.

Figure 5.2.7 shows the measured depth at the weirs from both EMWMF-2 and EMWMF3. This can be used to determine flow and calculate constituent flux over time. Water in EMWMF-2 was quite stable at 2 inches at the “vee” of the weir. However, during an extremely wet period in February 2019, the water from the weir was unable to drain due to the amount of runoff. Therefore, as expected, 4.25 inches was measured instead of 2 inches. The water depth going over the weir has been increasing due to the drainage ditch not removing surface water draining from the haul road and the weir. The ditch was cleaned out in September 2020, and the flow measured was more representative of the weir's past flow measurements.

The depth of water flowing from EMWMF-3 is dependent on stormwater (precipitation collected form the uncontaminated areas of the landfill site) and the discharge of contact water from the ponds and tanks on site. Before discharge, the water in the ponds and tanks are analyzed by DOE to make sure they meet the agreed upon discharge limits which are listed in Tennessee Ambient Water Quality Criteria for Fish and Aquatic Life for hexavalent chromium.

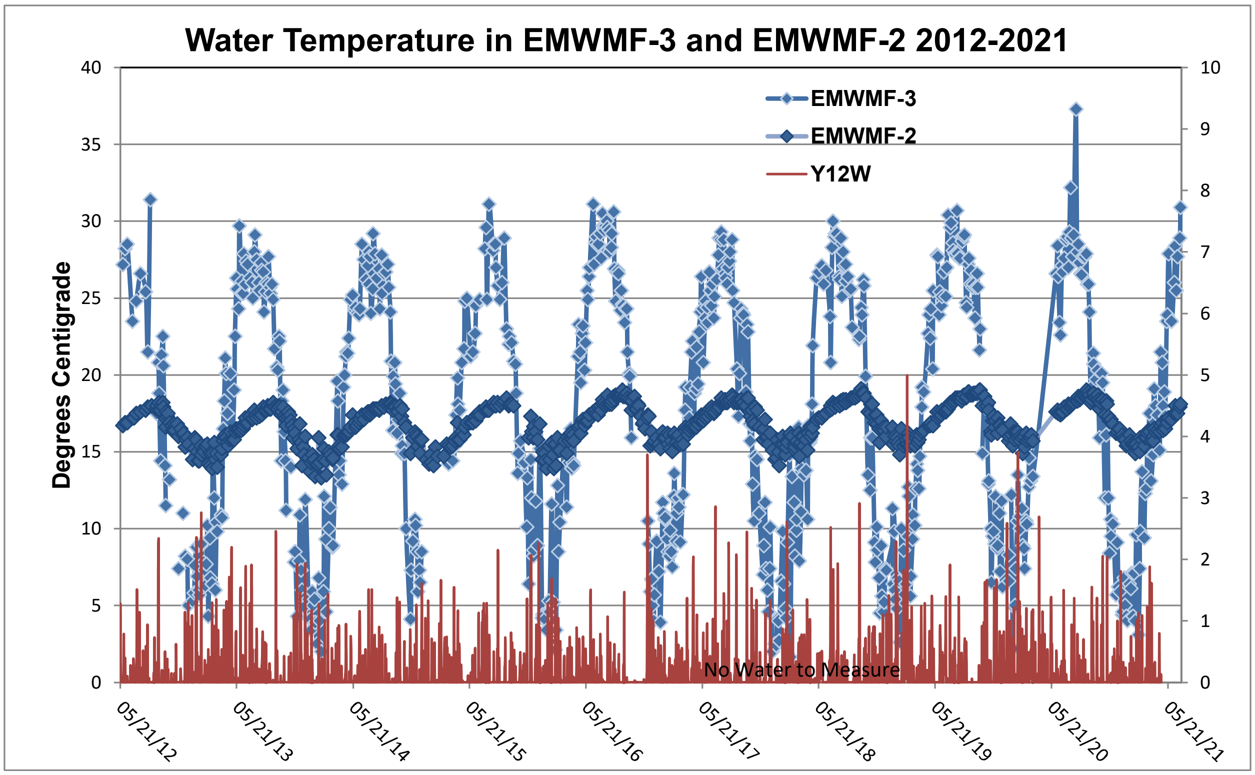



**Figure 5.2.4: Water Temperature in EMWMF-3 and EMWMF-2**

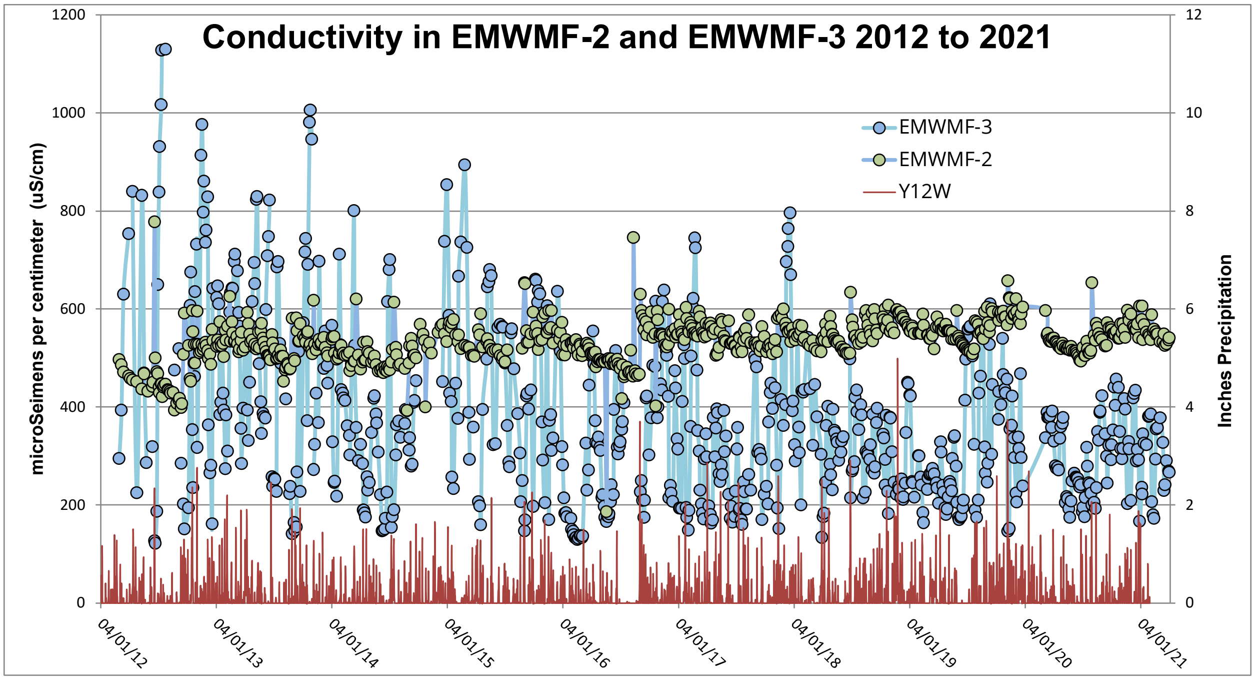



**Figure 5.2.5: Conductivity in EMWMF-3 and EMWMF-2**

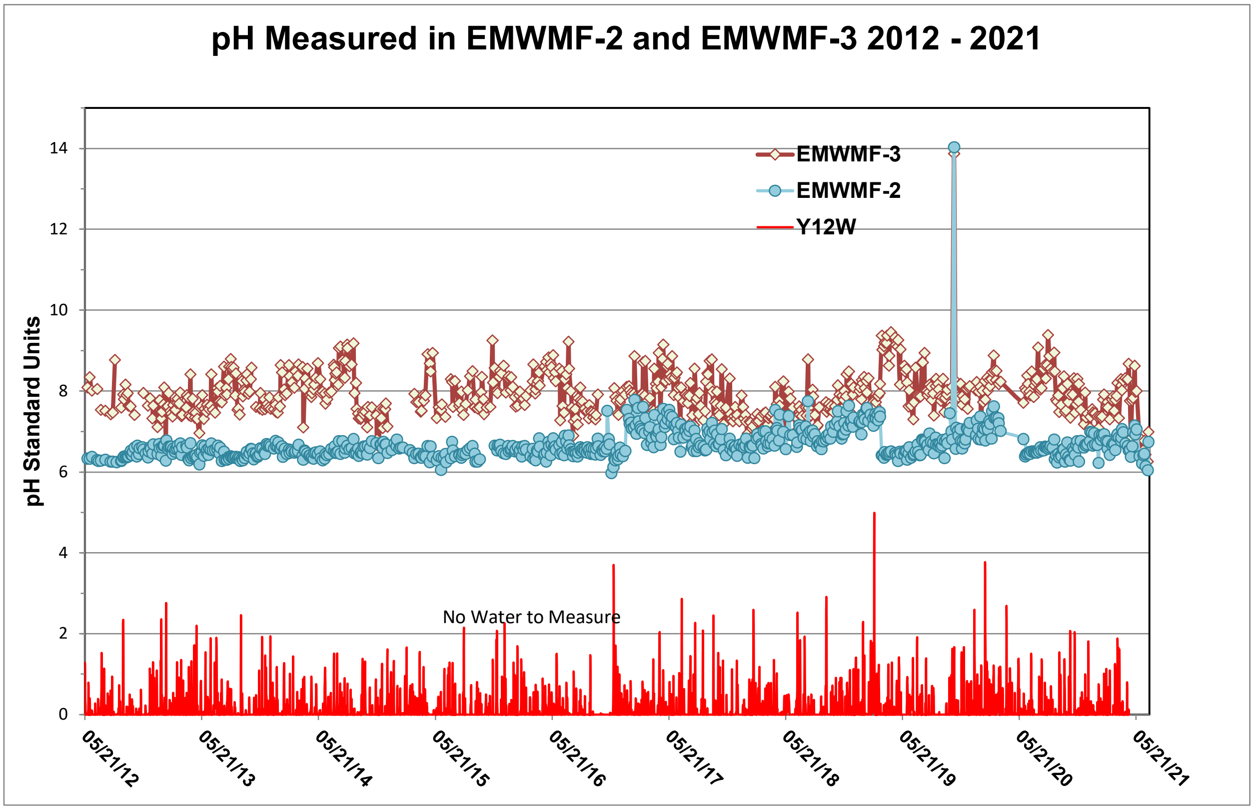



**Figure 5.2.6: pH Measured in EMWMF-2 and EMWMF-3**

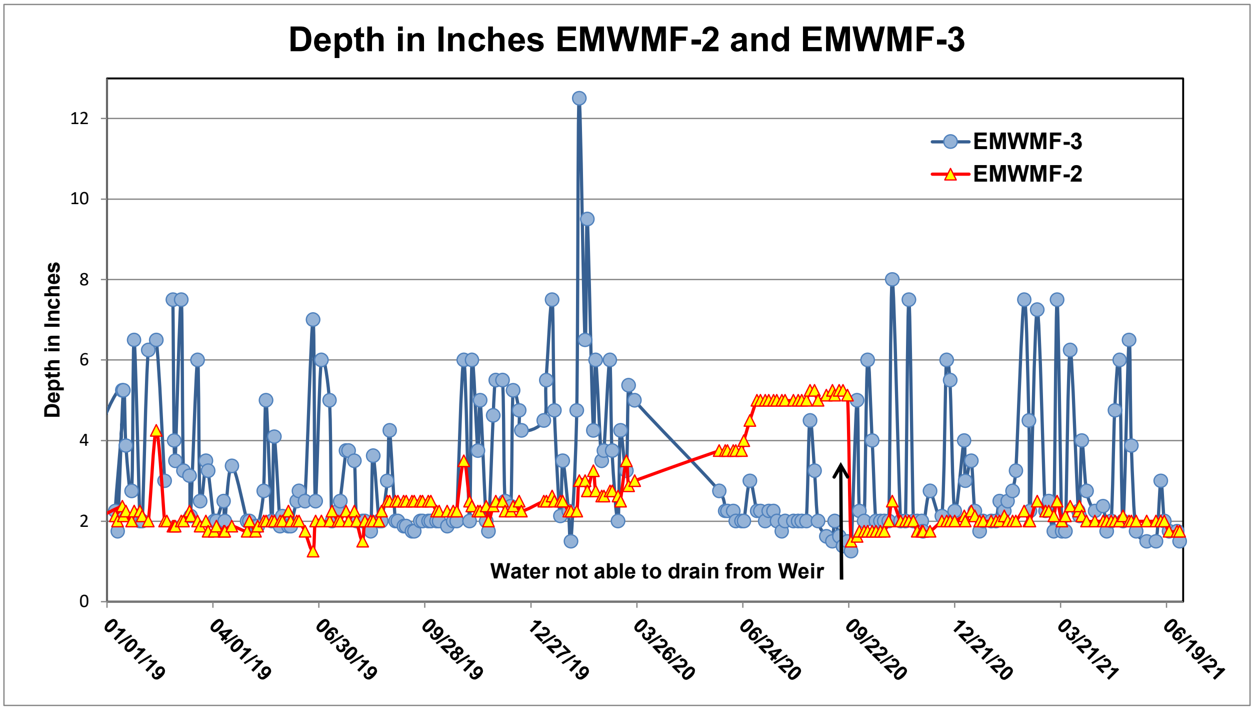



**Figure 5.2.7: FY 2021 Water Depth in Inches EMWMF-2 and EMWMF-3**

### TDEC DoR-OR EMWMF-2 and EMWMF-3 Metals Results Discussion

TDEC DoR-OR sampled for metals from EMWMF-2 five times and from EMWMF-3 four times. The metals make-up of EMWMF-2 is not remarkable for water from this area. Metals analyzed for both stations were arsenic, chromium, cobalt, copper, lead, nickel, uranium, vanadium, zinc and low-level mercury. A majority of the analytical results were non-detect. When aggregated, arsenic, copper, uranium, vanadium, zinc, and mercury had validated results. In EMWMF-2, arsenic, uranium, vanadium and copper had one detectable result while low-level mercury had two detectable results. In EMWMF-3, zinc had two, vanadium one and uranium had three detectable results. For both locations, Table 5.2.4 illustrates the maximum, minimum, total number of samples and the numbers of non-detects, estimated values (J), and detected concentrations. All metals were below the EPA and TDEC maximum contamination limits.

**Table 5.2.4 TDEC DoR-OR Analysis Metals Statistics Fiscal Year 2021**

| Station | Analyte | Maximum | Minimum | Result Qualification (ND) | Result Qualification (J) | Result Qualification (Detected) | Total Samples | Units |
|---|---|---|---|---|---|---|---|---|
| EMWMF-2 | Arsenic | <1.35 | <1.35 | 4 | - | 1 | 5 | µg/L |
| EMWMF-2 | Chromium | <3.49 | <3.11 | 5 | - | - | 5 | µg/L |
| EMWMF-2 | Cobalt | 0.48200 | <0.182 | 4 | 1 | - | 5 | µg/L |
| EMWMF-2 | Copper | 1.17 | <0.583 | 4 | - | 1 | 5 | µg/L |
| EMWMF-2 | Lead | 0.901 | <0.144 | 4 | 1 | - | 5 | µg/L |
| EMWMF-2 | Nickel | 0.881 | <0.270 | 3 | 2 | - | 5 | µg/L |
| EMWMF-2 | Uranium | 2.97 | 0.284 | - | 4 | 1 | 5 | µg/L |
| EMWMF-2 | Vanadium | 5.56 | <4.65 | 3 | 1 | 1 | 5 | ug/L |
| EMWMF-2 | Zinc | 8.86 | <3.47 | 2 | 2 | 1 | 5 | µg/L |
| EMWMF-2 | Low-Level Mercury | 0.00522 | 0.0007 | - | 3 | 2 | 5 | µg/L |
| EMWMF-3 | Arsenic | 1.42 | <0.607 | 3 | 1 | - | 4 | µg/L |
| EMWMF-3 | Chromium | <3.49 | <3.11 | 4 | - | - | 4 | µg/L |
| EMWMF-3 | Cobalt | 0.21 | <0.096 | 3 | 1 | - | 4 | µg/L |
| EMWMF-3 | Copper | 0.92 | <0.583 | 2 | 2 | - | 4 | µg/L |
| EMWMF-3 | Lead | <0.158 | <0.144 | 4 | - | - | 4 | µg/L |
| EMWMF-3 | Nickel | 0.836 | <0.423 | 1 | 3 | - | 4 | µg/L |
| EMWMF-3 | Uranium | 27.1 | 0.435 | - | 1 | 3 | 4 | µg/L |
| EMWMF-3 | Vanadium | 6.05 | <0.705 | 3 | - | 1 | 4 | µg/L |
| EMWMF-3 | Zinc | 5.87 | <4.64 | 2 | - | 2 | 4 | µg/L |
| EMWMF-3 | Low-Level Mercury | 0.00425 | 0.00134 | - | 4 | - | 4 | µg/L |

ND - not detected

J - estimated value

µg/L - micrograms per liter

**TDEC DoR-OR EMWMF-2 and EMWMF-3 Radionuclide Results Discussion**

Figures 5.2.8 through Figure 5.2.15 graph the radionuclide analyses from the sampling events during FY 2021 for both EMWMF-2 and EMWMF-3. EMWMF-2 was scheduled for bi-monthly sampling, but due to Covid-19, scheduling issues allowed for only five sampling events. EMWMF-3 was also scheduled for bi-monthly sampling, but scheduling issues pared the number to four events.

For EMWMF-2, most of the analytical results were at or below EMWMF project quantification levels or TDEC regulations. For EMWMF-3, gross beta activity was above the EPA drinking water standard (40 CFR Part 141, National Primary Drinking Water Regulations, Subparts B and G) of 50 pCi/L for the three reported sampling events (Figure 5.2.11). Gross alpha was above the drinking water standard of 15 pCi/L for two of the three sampling events (Figure 5.2.11). Technetium-99 and gross alpha were also elevated for the sampling events.

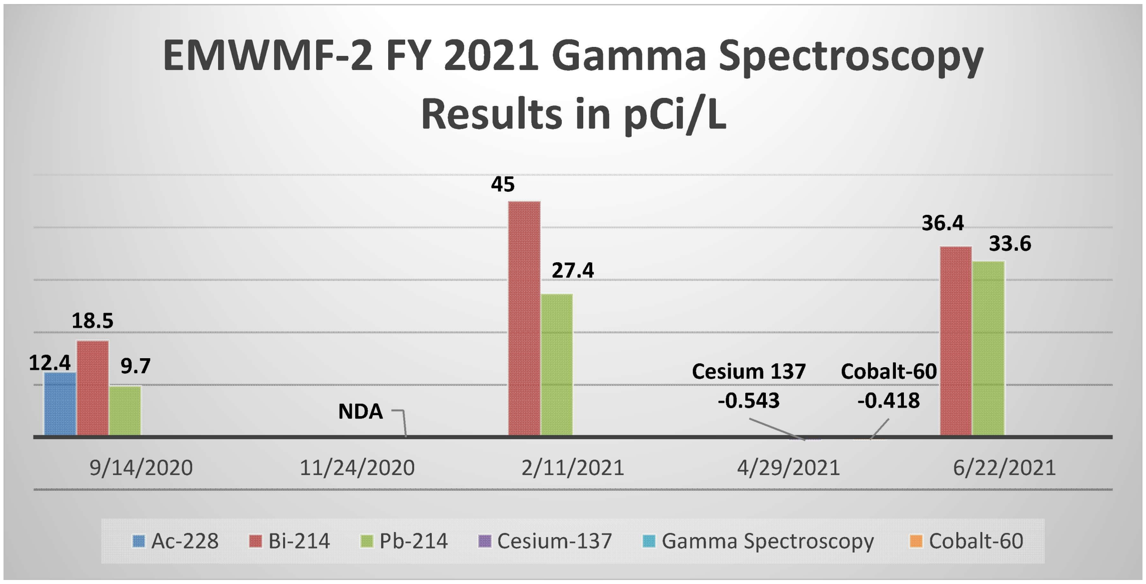



**Figure 5.2.8 EMWMF-2 Gamma Spectroscopy Activity Fiscal Year 2021**

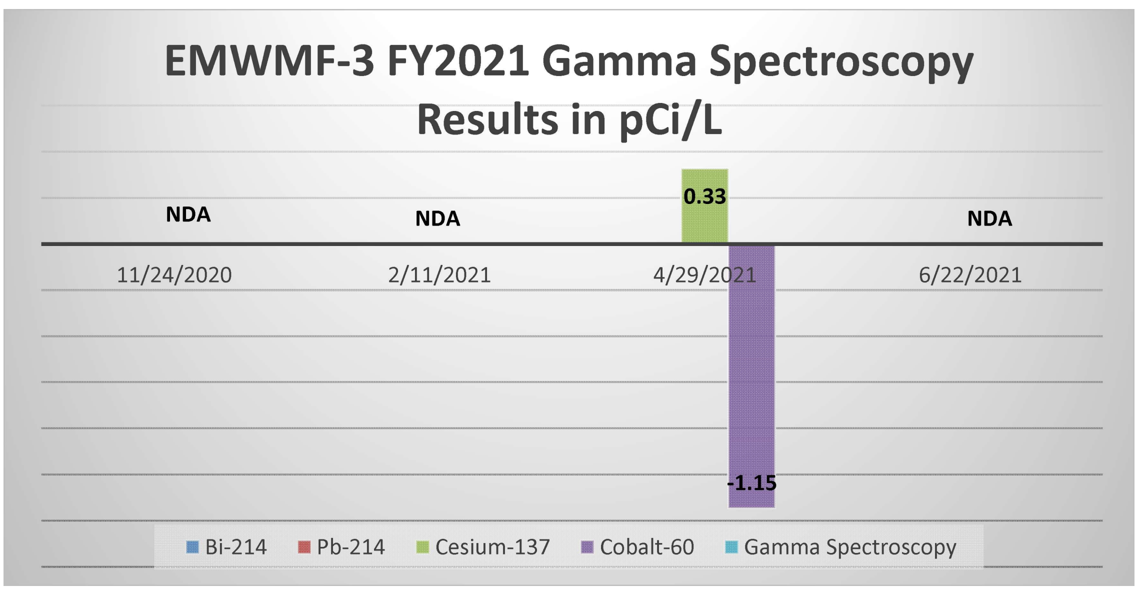



**Figure 5.2.9: EMWMF-3 Gamma Spectroscopy Activity Fiscal Year 2021**

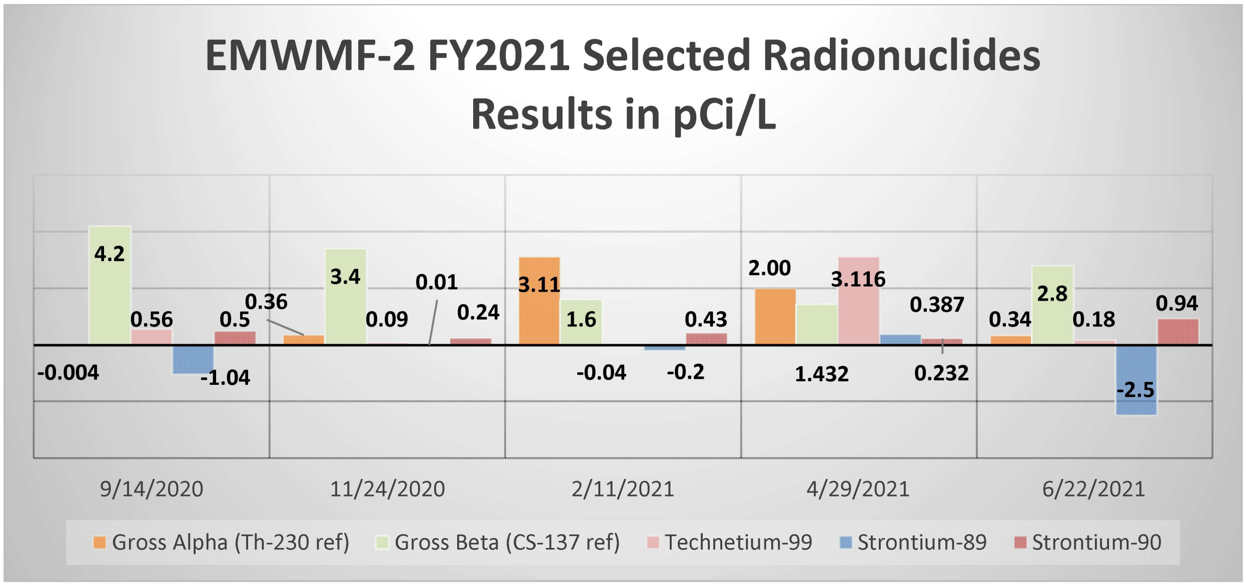



**Figure 5.2.10: EMWMF-2 FY2021 Selected Radionuclides Results in pCi/L**

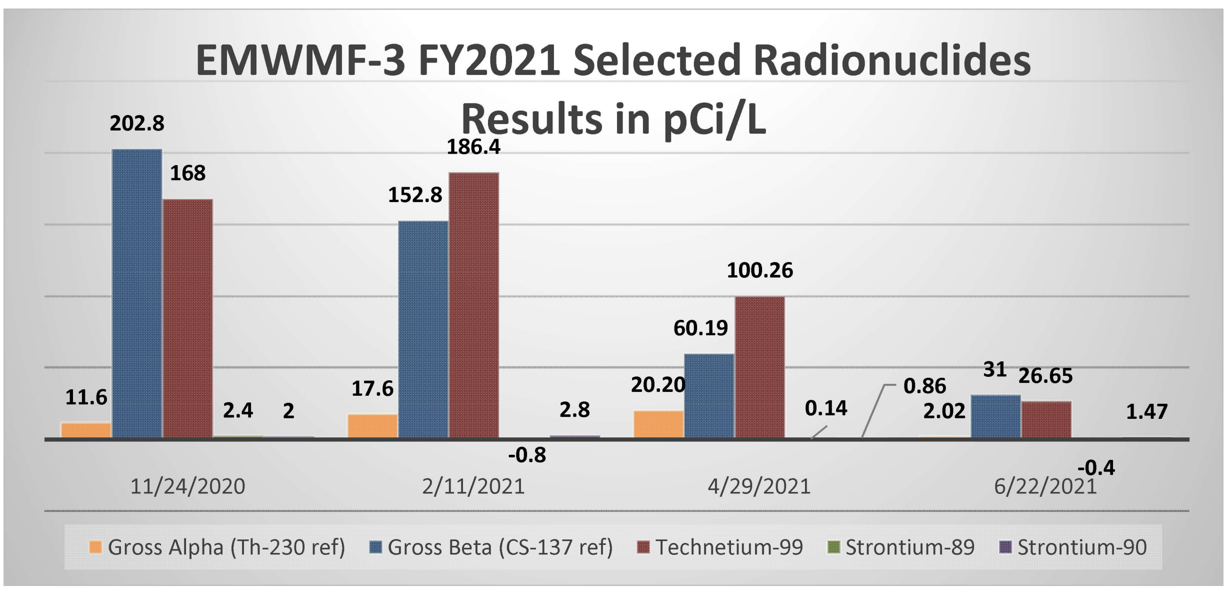



**Figure 5.2.11: EMWMF-3 FY2021 Selected Radionuclides Results in pCi/L**

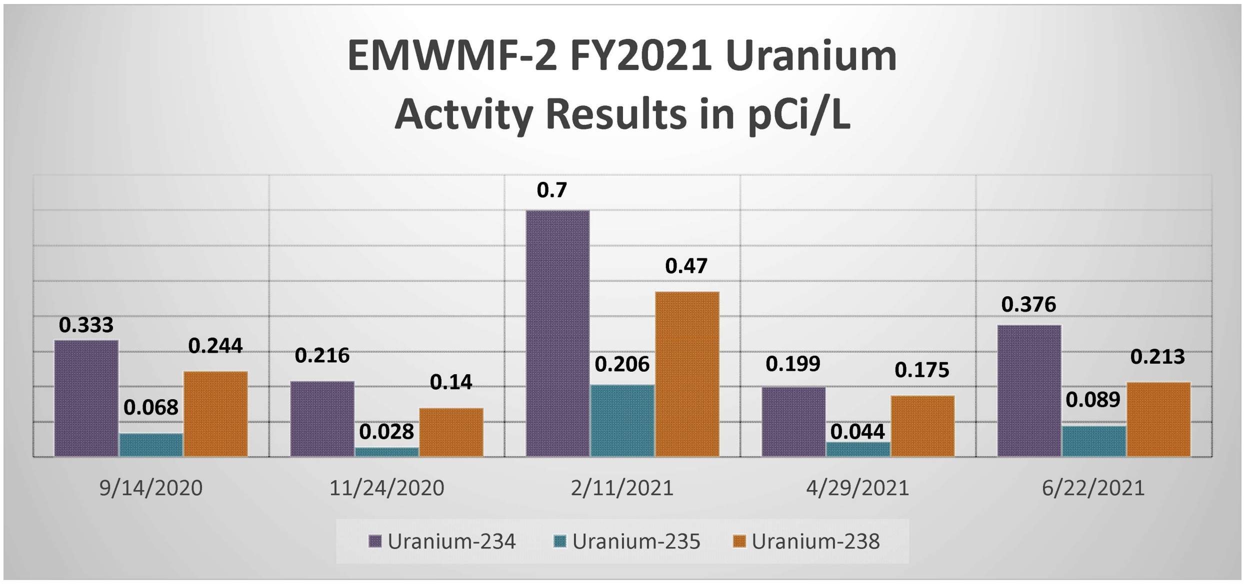



**Figure 5.2.12: EMWMF-2 FY2021 Uranium Activity Results in pCi/L**

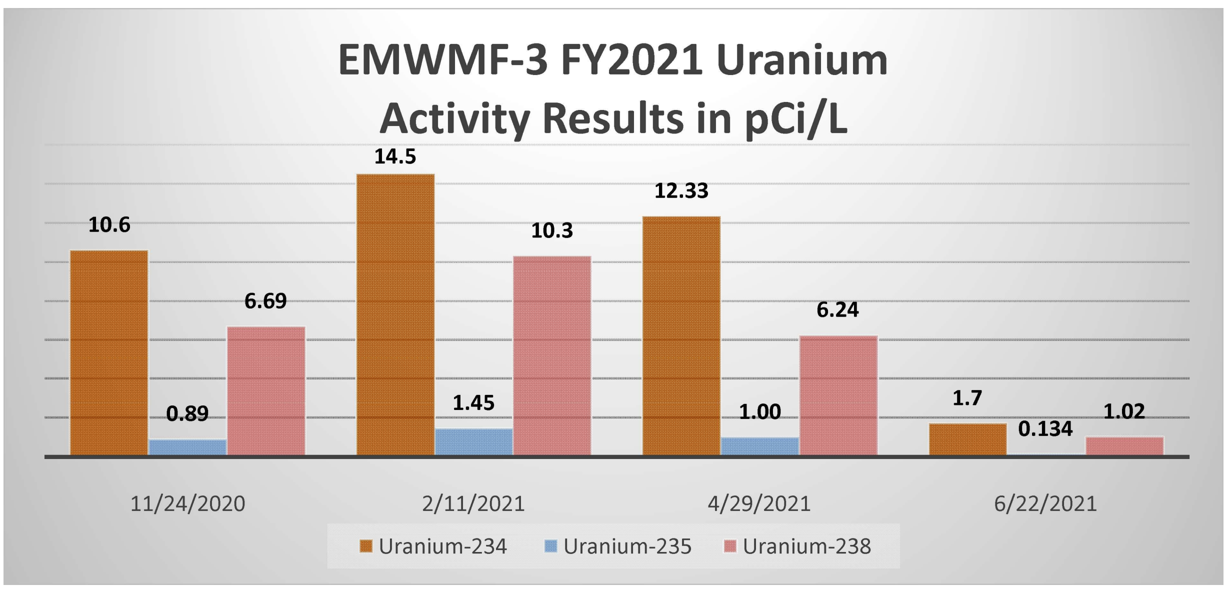



**Figure 5.2.13: EMWMF-3 FY2021 Uranium Activity Results in pCi/L**

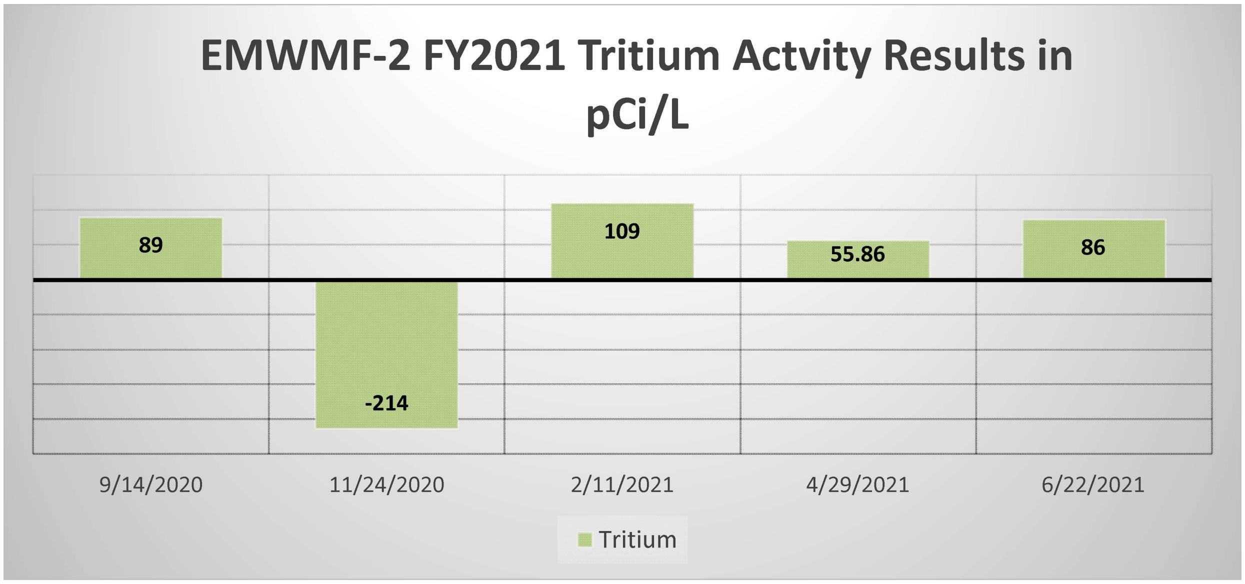



**Figure 5.2.14: EMWMF-2 FY2021 Tritium Activity Results in pCi/L**

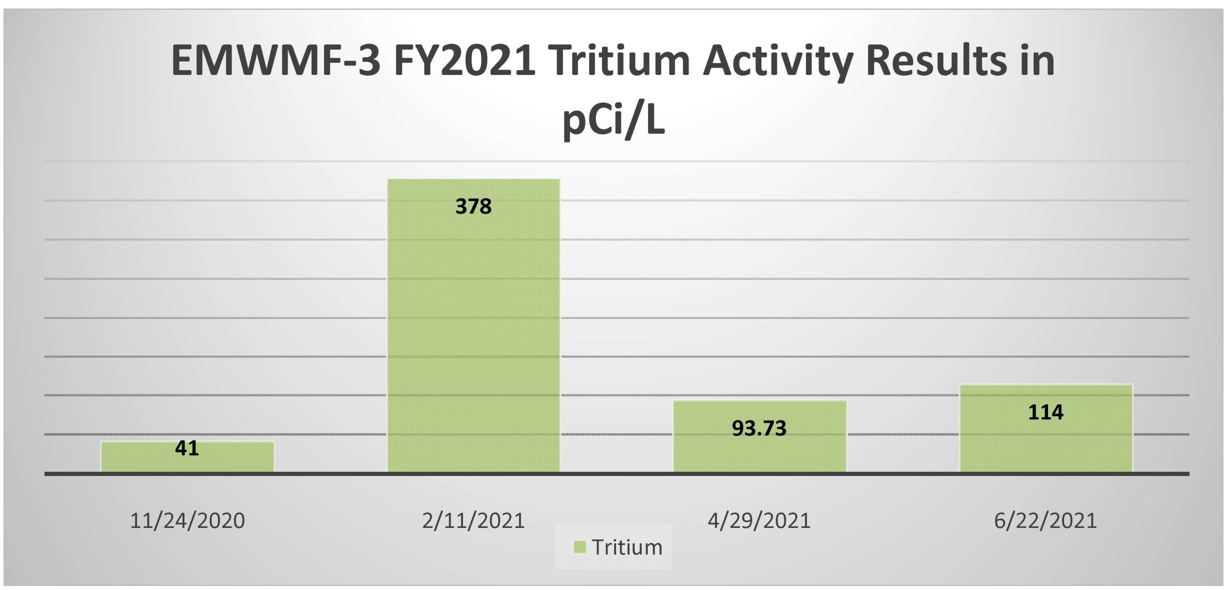



**Figure 5.2.15: EMWMF-3 FY2021 Tritium Activity Results in pCi/L**

**Summary of DOE Discharges and Sampling / TDEC's Review**

**2021 Fiscal Year EMWMF Contact Water Ponds and Tanks Discharge Status (summary of DOE data review)**

Before the start of this POP, FY2021, TDEC DoR-OR received DOE EMWMF Water Management Monday Morning Update Snapshots from Susan DePaoli and Annette Primrose (Figure 5.2.22). These Snapshots provided the approximated volume of water in the Contact Water Ponds (CWP), the Contact Water Tanks (CWT), the Cell 6 catchment and the Leachate Tanks. In addition, the Snapshot provided the normal maximum capacity, the total available volume for each of the ponds/tanks, the remaining available capacity in gallons and the percent full. Also provided were any hexavalent chromium ($Cr^{+6}$) concentrations, and other comments

**First Quarter: July 2020 through September 2020 (summary of DOE data)**

The approximated volume for the ponds/tanks/catchment provided by DOE, were put into a spreadsheet by TDEC, and if the next week's numbers were lower, they were marked as discharged. The numbers for the next week were subtracted from the previous week to determine approximately how much water was released to the Sediment Basin for that week. The discharged volumes were totaled by Pond/Tank and those volumes were totaled for the approximated volume discharged for the period. The first quarter period was from 6/22/2020 to 10/5/2020. Table 5.2.5 shows the total volume discharged since 6/22/2020. The approximated total discharged from the Contact Water Ponds was 455,000 gallons (Table 5.2.6). The approximated total volume of water discharged from the Contact Water Tanks was 634,500 gallons. With the Cell 6 catchment discharging 60,000 gallons, the total approximated volume of non-stormwater discharged to the Sediment Basin was 1,149,500 gallons for the period from 6/22/2020 to 10/5/2020 (Table 5.2.13).

## Table 5.2.5: EMWMF First Quarter FY21 Ponds/Tanks Weekly Approximated Volumes in Gallons

| Date | Cell 6 catchment | CWP #1 | CWP #2 | CWP #3 | CWP #4 | Pond Sub | CWT A | CWT B | CWT C | CWT D | Tank Sub | Total Water Stored |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/22/2020 | 80,000 | 17,000 | 39,000 | 10,000 | 15,000 | **195,000** | 23,500 | 188,000 | 23,500 | 141,000 | **470,000** | **665,000** |
| 6/29/2020 | 80,000 | 17,000 | 39,000 | 10,000 | 15,000 | **195,000** | 23,500 | 47,000 | 23,500 | 164,500 | **469,500** | **664,500** |
| 7/6/2020 | 80,000 | 25,000 | 56,000 | 19,000 | 15,000 | **195,000** | 23,500 | 188,000 | 23,500 | 235,000 | **470,000** | **665,000** |
| 7/13/2020 | 80,000 | 25,000 | 56,000 | 14,000 | 32,000 | **207,000** | 23,500 | 235,000 | 23,500 | 235,000 | **517,000** | **724,000** |
| 7/20/2020 | 40,000 | 25,000 | 56,000 | 25,000 | 15,000 | **161,000** | 23,500 | 23,500 | 23,500 | 23,500 | **94,000** | **255,000** |
| 7/27/2020 | 80,000 | 77,000 | 48,000 | 19,000 | 15,000 | **239,000** | 23,500 | 47,000 | 23,500 | 23,500 | **117,500** | **356,500** |
| 8/3/2020 | 80,000 | 321,000 | 48,000 | 10,000 | 15,000 | **474,000** | 23,500 | 47,000 | 23,500 | 23,500 | **117,500** | **591,500** |
| 8/10/2020 | 80,000 | 383,000 | 74,000 | 19,000 | 26,000 | **582,000** | 23,500 | 47,000 | 47,000 | 23,500 | **141,000** | **723,000** |
| 8/17/2020 | 80,000 | 415,000 | 74,000 | 118,000 | 26,000 | **713,000** | 23,500 | 47,000 | 47,000 | 23,500 | **141,000** | **854,000** |
| 8/24/2020 | 100,000 | 25,000 | 74,000 | 140,000 | 26,000 | **365,000** | 23,500 | 47,000 | 47,000 | 23,500 | **141,000** | **506,000** |
| 8/31/2020 | 80,000 | 33,000 | 84,000 | 259,000 | 45,000 | **501,000** | 23,500 | 47,000 | 47,000 | 23,500 | **141,000** | **642,000** |
| 9/8/2020 | 80,000 | 41,000 | 93,000 | 246,000 | 52,000 | **512,000** | 23,500 | 47,000 | 47,000 | 23,500 | **141,000** | **653,000** |
| 9/14/2020 | 80,000 | 41,000 | 93,000 | 259,000 | 52,000 | **525,000** | **0** | 23,500 | 47,000 | 23,500 | **94,000** | **619,000** |
| 9/21/2020 | 80,000 | 41,000 | 93,000 | 259,000 | 45,000 | **518,000** | **0** | 47,000 | 70,500 | 23,500 | **141,000** | **659,000** |
| 9/28/2020 | 80,000 | 351,000 | 93,000 | 343,000 | 45,000 | **912,000** | **0** | 47,000 | 47,000 | 23,500 | **117,500** | **1,029,500** |
| 10/5/2020 | 80,000 | 448,000 | 190,000 | 358,000 | 60,000 | **1,136,000** | 23,500 | 47,000 | 94,000 | 23,500 | **188,000** | **1,324,000** |

(highlighted) Pond,Tank or Catchment volume before discharge

CWP - Contact Water Pond

CWT - Contact Water Tank

## Table 5.2.6: First Quarter Calculated Approximated Volumes Discharged 6/22/20 to 10/5/2020 in Gallons

| | Cell 6 Catchment | | CWP #1 | | CWP #2 | | CWP #3 | | CWP #4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | Meas. Vol. | Discharged | Meas. Vol. | Discharged | Meas. Vol. | Discharged | Meas. Vo | Discharged | Meas. Vol. | Discharged | |
| 6/22/2020 | 80000 | 0 | 17000 | 0 | 39000 | 0 | 10000 | 0 | 15000 | 0 | |
| 6/29/2020 | 80000 | 0 | 17000 | 0 | 39000 | 0 | 10000 | 0 | 15000 | 0 | |
| 7/6/2020 | 80000 | 0 | 25000 | 0 | 56000 | 0 | 19000 | 0 | 15000 | 0 | |
| 7/13/2020 | 80000 | 0 | 25000 | 0 | 56000 | 0 | 14000 | 5000 | 32000 | 0 | |
| 7/20/2020 | 40000 | 40000 | 25000 | 0 | 56000 | 0 | 25000 | 0 | 15000 | 17000 | |
| 7/27/2020 | 80000 | 0 | 77000 | 0 | 48000 | 8000 | 19000 | 6000 | 15000 | 0 | |
| 8/3/2020 | 80000 | 0 | 321000 | 0 | 48000 | 0 | 10000 | 9000 | 15000 | 0 | |
| 8/10/2020 | 80000 | 0 | 383000 | 0 | 74000 | 0 | 19000 | 0 | 26000 | 0 | |
| 8/17/2020 | 80000 | 0 | 415000 | 0 | 74000 | 0 | 118000 | 0 | 26000 | 0 | |
| 8/24/2020 | 100000 | 0 | 25000 | 390000 | 74000 | 0 | 140000 | 0 | 26000 | 0 | |
| 8/31/2020 | 80000 | 20000 | 33000 | 0 | 84000 | 0 | 259000 | 0 | 45000 | 0 | |
| 9/8/2020 | 80000 | 0 | 41000 | 0 | 93000 | 0 | 246000 | 13000 | 52000 | 0 | |
| 9/14/2020 | 80000 | 0 | 41000 | 0 | 93000 | 0 | 259000 | 0 | 52000 | 0 | |
| 9/21/2020 | 80000 | 0 | 41000 | 0 | 93000 | 0 | 259000 | 0 | 45000 | 7000 | |
| 9/28/2020 | 80000 | 0 | 351000 | 0 | 93000 | 0 | 343000 | 0 | 45000 | 0 | |
| 10/5/2020 | 80000 | 0 | 448000 | 0 | 190000 | 0 | 358000 | 0 | 60000 | 0 | |
| **SubTotal** | | **60,000** | | **390,000** | | **8,000** | | **33,000** | | **24,000** | |
| **SubTotal** | | **60000** | | | | | | | | **Pond Sub** | **455,000** |

| | CWT A | | CWT B | | CWT C | | CWT D | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | Meas. Vol. | Discharged | Meas. Vol. | Discharged | Meas. Vol. | Discharged | Meas. Vo | Discharged | | |
| 6/22/2020 | 23500 | 0 | 188000 | 0 | 23500 | 0 | 141000 | 0 | | |
| 6/29/2020 | 23500 | 0 | 47000 | 141000 | 23500 | 0 | 164500 | 0 | | |
| 7/6/2020 | 23500 | 0 | 188000 | 0 | 23500 | 0 | 235000 | 0 | | |
| 7/13/2020 | 23500 | 0 | 235000 | 0 | 23500 | 0 | 235000 | 0 | | |
| 7/20/2020 | 23500 | 0 | 23500 | 211500 | 23500 | 0 | 23500 | 211500 | | |
| 7/27/2020 | 23500 | 0 | 47000 | 0 | 23500 | 0 | 23500 | 0 | | |
| 8/3/2020 | 23500 | 0 | 47000 | 0 | 23500 | 0 | 23500 | 0 | | |
| 8/10/2020 | 23500 | 0 | 47000 | 0 | 47000 | 0 | 23500 | 0 | | |
| 8/17/2020 | 23500 | 0 | 47000 | 0 | 47000 | 0 | 23500 | 0 | | |
| 8/24/2020 | 23500 | 0 | 47000 | 0 | 47000 | 0 | 23500 | 0 | | |
| 8/31/2020 | 23500 | 0 | 47000 | 0 | 47000 | 0 | 23500 | 0 | | |
| 9/8/2020 | 23500 | 0 | 47000 | 0 | 47000 | 0 | 23500 | 0 | | |
| 9/14/2020 | 0 | 23500 | 23500 | 23500 | 47000 | 0 | 23500 | 0 | | |
| 9/21/2020 | 0 | 0 | 47000 | 0 | 70500 | 0 | 23500 | 0 | | |
| 9/28/2020 | 0 | 0 | 47000 | 0 | 47000 | 23500 | 23500 | 0 | | |
| 10/5/2020 | 23500 | 0 | 47000 | 0 | 94000 | 0 | 23500 | 0 | | |
| **SubTotal** | | **23,500** | | **376,000** | | **23,500** | | **211,500** | | **Total Water Discharged** |
| **SubTotal** | | | | | | | | **Tank Sub** | **634,500** | **1,149,500** |

CWP contact water pond
CWT contact water tank
**Losses:** Does not take into account: incorrect tallying, evaporation

## Second Quarter: October 2020 through December 2020 (summary of DOE data review)

The approximated volume for the ponds/tanks/catchment were put into a spreadsheet and if the next week's numbers were lower, they were marked as discharged. The numbers for the next week were subtracted from the previous week to determine how much water was released to the Sediment Basin for that week. The discharged volumes were totaled by Pond/Tank and those volumes were totaled for the approximated volume discharged for the period. The second quarter period was from 10/5/2020 to 1/4/2021. Table 5.2.7 shows the total volume discharged since 10/5/2020. The approximated total discharged from the Contact Water Ponds for the second quarter was 2,555,000 gallons (Table 5.2.8). The approximated total volume of water discharged from the Contact Water Tanks for the second quarter was 1,269,000 gallons. With the Cell 6 catchment discharging 40,000 gallons, the total approximated volume of non-stormwater discharged to the Sediment Basin was 3,864,000 gallons for the period from 10/5/2020 ending 1/4/2021 (Table 5.2.13).

### Table 5.2.7: EMWMF Second Quarter FY21 Ponds/Tanks Weekly Approximated Volumes in Gallons

| Date | Cell 6 catchment | CWP #1 | CWP #2 | CWP #3 | CWP #4 | Pond Sub | CWT A | CWT B | CWT C | CWT D | Tank Sub | Total Water Stored |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/5/2020 | 80,000 | 448,000 | 190,000 | 358,000 | 60,000 | 1,056,000 | 23,500 | 47,000 | 94,000 | 23,500 | 188,000 | 1,324,000 |
| 10/12/2020 | 80,000 | 186,000 | 350,000 | 3,000 | 60,000 | 599,000 | 23,500 | 94,000 | 70,500 | 23,500 | 211,500 | 890,500 |
| 10/19/2020 | 80,000 | 199,000 | 411,000 | 19,000 | 45,000 | 674,000 | 23,500 | 47,000 | 117,500 | 23,500 | 211,500 | 965,500 |
| 10/26/2020 | 100,000 | 199,000 | 411,000 | 19,000 | 38,000 | 667,000 | 23,500 | 47,000 | 94,000 | 0 | 164,500 | 931,500 |
| 11/2/2020 | 100,000 | 431,000 | 103,000 | 388,000 | 38,000 | 960,000 | 47,000 | 164,500 | 211,500 | 211,500 | 634,500 | 1,694,500 |
| 11/9/2020 | 100,000 | 448,000 | 167,000 | 388,000 | 32,000 | 1,035,000 | 70,500 | 188,000 | 211,500 | 211,500 | 681,500 | 1,816,500 |
| 11/16/2020 | 100,000 | 17,000 | 167,000 | 19,000 | 32,000 | 235,000 | 211,500 | 211,500 | 211,500 | 117,500 | 752,000 | 1,087,000 |
| 11/23/2020 | 80,000 | 9,000 | 202,000 | 38,000 | 15,000 | 264,000 | 211,500 | 23,500 | 211,500 | 141,000 | 587,500 | 931,500 |
| 11/30/2020 | 80000 | 17000 | 202000 | 6000 | 26000 | 251,000 | 0 | 47000 | 0 | 141000 | 188,000 | 519,000 |
| 12/7/2020 | 80000 | 33000 | 240000 | 14000 | 45000 | 332,000 | 23500 | 47000 | 23500 | 211500 | 282,000 | 385,500 |
| 12/14/2020 | 100000 | 33000 | 307000 | 14000 | 38000 | 392,000 | 23500 | 47000 | 23500 | 188000 | 258,500 | 382,000 |
| 12/21/2020 | 80000 | 50000 | 476000 | 25000 | 52000 | 603,000 | 23,500 | 211500 | 23500 | 23500 | 258,500 | 362,000 |
| 12/28/2020 | 80000 | 264000 | 476000 | 31000 | 52000 | 823,000 | 164,500 | 211500 | 23500 | 23500 | 258,500 | 503,000 |
| 1/4/2021 | 80000 | 307000 | 23000 | 10000 | 32000 | 372,000 | 211500 | 211500 | 23500 | 23500 | 258,500 | 550,000 |

Pond,Tank or Catchment volume before discharge

CWP - Contact Water Pond

CWT - Contact Water Tank

Losses -Does not take into account: incorrect tallying, evaporation

## Table 5.2.8: Second Quarter Calculated Approximated Volumes Discharged 10/5/2020 to 1/4/2021 in Gallons

| | Cell 6 Catchment | | CWP #1 | | CWP #2 | | CWP #3 | | CWP #4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Meas. Vol | Discharge | Meas. Vol | Discharge | Meas. Vol | Discharge | Meas. Vol | Discharge | Meas. Vol | Discharged | |
| 10/5/2020 | 80000 | 0 | 448000 | 0 | 190000 | 0 | 358000 | 0 | 60000 | 0 | |
| 10/12/2020 | 80000 | 0 | 186000 | 262000 | 350000 | 0 | 3000 | 355000 | 60000 | 0 | |
| 10/19/2020 | 80000 | 0 | 199000 | 0 | 411000 | 0 | 19000 | 0 | 45000 | 15000 | |
| 10/26/2020 | 100000 | 0 | 199000 | 0 | 411000 | 0 | 19000 | 0 | 38000 | 7000 | |
| 11/2/2020 | 100000 | 0 | 431000 | 0 | 103000 | 308000 | 388000 | 0 | 38000 | 0 | |
| 11/9/2020 | 100000 | 0 | 448000 | 0 | 167000 | 244000 | 388000 | 0 | 32000 | 6000 | |
| 11/16/2020 | 100000 | 0 | 17000 | 431000 | 167000 | 0 | 19000 | 369000 | 32000 | 0 | |
| 11/23/2020 | 80000 | 20000 | 9000 | 8000 | 202000 | 0 | 38000 | 0 | 15000 | 17000 | |
| 11/30/2020 | 80000 | 0 | 17000 | 0 | 202000 | 0 | 6000 | 32000 | 26000 | 0 | |
| 12/7/2020 | 80000 | 0 | 33000 | 0 | 24000 | 0 | 14000 | 0 | 45000 | 0 | |
| 12/14/2020 | 100000 | 0 | 33000 | 0 | 30700 | 0 | 14000 | 0 | 38000 | 7000 | |
| 12/21/2020 | 80000 | 20000 | 50000 | 0 | 476000 | 0 | 25000 | 0 | 52000 | 0 | |
| 12/28/2020 | 80000 | 0 | 264000 | 0 | 476000 | 0 | 31000 | 0 | 52000 | 0 | |
| 1/4/2021 | 80000 | 0 | 307000 | 0 | 23000 | 453000 | 10000 | 21000 | 32000 | 20000 | |
| **SubTotal** | | **40,000** | | **701,000** | | **1,005,000** | | **777,000** | | **72,000** | |
| **SubTotal** | | **40,000** | | | | | | | | **Pond Sub** | **2,555,000** |

| | CWT A | | CWT B | | CWT C | | CWT D | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Meas. Vol. | Discharged | Meas. Vol. | Discharged | Meas. Vol. | Discharged | Meas. Vol. | Discharged | | |
| 10/5/2020 | 23500 | 0 | 47000 | 0 | 94000 | 0 | 23500 | 0 | | |
| 10/12/2020 | 23500 | 0 | 94000 | 0 | 70500 | 23500 | 23500 | 0 | | |
| 10/19/2020 | 23500 | 0 | 47000 | 47000 | 117500 | 0 | 23500 | 0 | | |
| 10/26/2020 | 23500 | 0 | 47000 | 0 | 94000 | 23500 | 0 | 23500 | | |
| 11/2/2020 | 47000 | 0 | 164500 | | 211500 | | 211500 | 0 | | |
| 11/9/2020 | 23500 | 23500 | 47000 | 117500 | 94000 | 117500 | 211500 | 0 | | |
| 11/16/2020 | 211500 | | 211500 | | 211500 | | 117500 | 94000 | | |
| 11/23/2020 | 211500 | | 23500 | 188000 | 211500 | | 141000 | 0 | | |
| 11/30/2020 | 0 | 211500 | 47000 | 0 | 0 | 211500 | 141000 | 0 | | |
| 12/7/2020 | 23500 | 0 | 47000 | 0 | 23500 | 0 | 211500 | 0 | | |
| 12/14/2020 | 23500 | 0 | 47000 | 0 | 23500 | 0 | 188000 | 23500 | | |
| 12/21/2020 | 23500 | 0 | 211500 | 0 | 23500 | 0 | 23500 | 164500 | | |
| 12/28/2020 | 164500 | 0 | 211500 | 0 | 23500 | 0 | 23500 | 0 | | |
| 1/4/2021 | 211500 | 0 | 211500 | 0 | 23500 | 0 | 23500 | 0 | | |
| **SubTotal** | | **235,000** | | **352,500** | | **376,000** | | **305,500** | | **Total Water Discharged** |
| **SubTotal** | | | | | | | | **Tank Sub** | **1,269,000** | **3,864,000** |

CWP contact water pond
CWT contact water tank
Losses: Does not take into account: incorrect tallying, evaporation

**Third Quarter: January 2021 through March 2021 (summary of DOE data review)**

The approximated volume for the ponds/tanks/catchment were put into a spreadsheet and if the next week's numbers were lower, they were marked as discharged. The numbers for the next week were subtracted from the previous week to determine how much water was released to the Sediment Basin for that week. The discharged volumes were totaled by Pond/Tank and those volumes were totaled for the approximated volume discharged for the period. The third quarter period was from 1/11/2021 to 4/5/2021. Table 5.2.9 shows the total volume discharged since 1/11/2021. The approximated total discharged from the Contact Water Ponds for the third quarter was 1,719,000 gallons (Table 5.2.10). The approximated total volume of water discharged from the Contact Water Tanks for the third quarter was 963,500 gallons. With the Cell 6 catchment discharging 40,000 gallons, the total approximated volume of non-stormwater (NSW) discharged to the Sediment Basin was 2,722,500 gallons for the period from 1/11/2020 ending 4/5/2021 (Table 5.2.13).

**Table 5.2.9: EMWMF Third Quarter FY21 Ponds/Tanks Weekly Approximated Volumes in Gallons** Note: Yellow blocks indicate discharges for the previous week

| Date | Cell 6 catchment | CWP #1 | CWP #2 | CWP #3 | CWP #4 | Pond Sub | CWT A | CWT B | CWT C | CWT D | Tank Sub | Total Water Stored |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/22/2020 | 80,000 | 17,000 | 39,000 | 10,000 | 15,000 | 196,000 | 23,500 | 188,000 | 23,500 | 141,000 | 470,000 | 666,000 |
| 6/29/2020 | 80,000 | 17,000 | 39,000 | 10,000 | 15,000 | 196,000 | 23,500 | 47,000 | 23,500 | 164,500 | 469,500 | 664,500 |
| 7/6/2020 | 80,000 | 25,000 | 56,000 | 19,000 | 15,000 | 196,000 | 23,500 | 188,000 | 23,500 | 235,000 | 470,000 | 666,000 |
| 7/13/2020 | 80,000 | 25,000 | 56,000 | 14,000 | 32,000 | 207,000 | 23,500 | 235,000 | 23,500 | 235,000 | 517,000 | 724,000 |
| 7/20/2020 | 40,000 | 25,000 | 56,000 | 25,000 | 15,000 | 161,000 | 23,500 | 23,500 | 23,500 | 23,500 | 94,000 | 255,000 |
| 7/27/2020 | 80,000 | 77,000 | 48,000 | 19,000 | 15,000 | 239,000 | 23,500 | 47,000 | 23,500 | 23,500 | 117,500 | 356,500 |
| 8/3/2020 | 80,000 | 321,000 | 48,000 | 10,000 | 15,000 | 474,000 | 23,500 | 47,000 | 23,500 | 23,500 | 117,500 | 591,500 |
| 8/10/2020 | 80,000 | 383,000 | 74,000 | 19,000 | 26,000 | 582,000 | 23,500 | 47,000 | 47,000 | 23,500 | 141,000 | 723,000 |
| 8/17/2020 | 80,000 | 415,000 | 74,000 | 118,000 | 26,000 | 713,000 | 23,500 | 47,000 | 47,000 | 23,500 | 141,000 | 854,000 |
| 8/24/2020 | 100,000 | 25,000 | 74,000 | 140,000 | 26,000 | 365,000 | 23,500 | 47,000 | 47,000 | 23,500 | 141,000 | 506,000 |
| 8/31/2020 | 80,000 | 33,000 | 84,000 | 259,000 | 45,000 | 501,000 | 23,500 | 47,000 | 47,000 | 23,500 | 141,000 | 642,000 |
| 9/8/2020 | 80,000 | 41,000 | 93,000 | 246,000 | 52,000 | 512,000 | 23,500 | 47,000 | 47,000 | 23,500 | 141,000 | 653,000 |
| 9/14/2020 | 80,000 | 41,000 | 93,000 | 259,000 | 52,000 | 525,000 | 0 | 23,500 | 47,000 | 23,500 | 94,000 | 619,000 |
| 9/21/2020 | 80,000 | 41,000 | 93,000 | 259,000 | 45,000 | 518,000 | 0 | 47,000 | 70,500 | 23,500 | 141,000 | 659,000 |
| 9/28/2020 | 80,000 | 351,000 | 93,000 | 343,000 | 45,000 | 912,000 | 0 | 47,000 | 47,000 | 23,500 | 117,500 | 1,029,500 |
| 10/5/2020 | 80,000 | 448,000 | 190,000 | 358,000 | 60,000 | 1,136,000 | 23,500 | 47,000 | 94,000 | 23,500 | 188,000 | 1,324,000 |

Pond, Tank or Catchment volume before discharge

CWP - Contact Water Pond

CWT - Contact Water Tank

## Table 5.2.10: Third Quarter Calculated Approximated Volumes Discharged 1/11/2021 to 4/5/2021 in Gallons

| | Cell 6 Catchment | | CWP #1 | | CWP #2 | | CWP #3 | | CWP #4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** |
| 1/11/2021 | 80000 | 0 | 321000 | 0 | 31000 | 0 | 14000 | 0 | 20000 | 12000 |
| 1/19/2021 | 80000 | 0 | 367000 | 0 | 39000 | 0 | 19000 | 0 | 38000 | 0 |
| 1/25/2021 | 80000 | 0 | 398000 | 0 | 39000 | 0 | 14000 | 5000 | 11000 | 27000 |
| 2/1/2021 | 80000 | 0 | 415000 | 0 | 74000 | 0 | 25000 | 0 | 7000 | 4000 |
| 2/8/2021 | 100000 | 0 | 17000 | 398000 | 65000 | 9000 | 38000 | 0 | 15000 | 0 |
| 2/15/2021 | 100000 | 0 | 25000 | 0 | 65000 | 0 | 38000 | 0 | 11000 | 4000 |
| 2/22/2021 | 100000 | 0 | 41000 | 0 | 74000 | 0 | 173000 | 0 | 26000 | 0 |
| 3/1/2021 | 120000 | 0 | 186000 | 0 | 23000 | 51000 | 314000 | 0 | 45000 | 0 |
| 3/8/2021 | 80000 | 40000 | 431000 | 0 | 145000 | 0 | 358000 | 0 | 60000 | |
| 3/15/2021 | 80000 | 0 | 431000 | 0 | 156000 | 0 | 6000 | 352000 | 45000 | 15000 |
| 3/18/2021 | 80000 | 0 | 9000 | 422000 | 443000 | 0 | 6000 | 0 | 60000 | 0 |
| 3/22/2021 | 80000 | 0 | 9000 | 0 | 443000 | 0 | 6000 | 0 | 60000 | 0 |
| 3/29/2021 | 80000 | 0 | 415000 | 0 | 443000 | 0 | 358000 | 0 | 164000 | 0 |
| 4/5/2021 | 80000 | 0 | 415000 | 0 | 23000 | 420000 | 373000 | 0 | 379000 | 0 |
| | | | | | | | | | | |
| **SubTotal** | | **40,000** | | **820,000** | | **480,000** | | **357,000** | | **62,000** |
| **SubTotal** | | **40,000** | | | | | | | **Pond Sub** | **1,719,000** |

| | CWT A | | CWT B | | CWT C | | CWT D | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** |
| 1/11/2021 | 211500 | 0 | 47000 | 0 | 23500 | 0 | 70500 | 0 |
| 1/19/2021 | 23500 | 0 | 47000 | 0 | 47000 | 0 | 47000 | 23500 |
| 1/25/2021 | 23500 | 0 | 47000 | 0 | 23500 | 23500 | 47000 | 0 |
| 2/1/2021 | 23500 | 0 | 47000 | 0 | 94000 | 0 | 211500 | 0 |
| 2/8/2021 | 23500 | 0 | 47000 | 0 | 141000 | 0 | 23500 | 188000 |
| 2/15/2021 | 23500 | 0 | 141000 | 0 | 211500 | 0 | 117500 | 0 |
| 2/22/2021 | 211500 | 0 | 211500 | 0 | 211500 | 0 | 211500 | 0 |
| 3/1/2021 | 211500 | 0 | 211500 | 0 | 211500 | 0 | 211500 | 0 |
| 3/8/2021 | 23500 | 188000 | 47000 | 164500 | 23500 | 188000 | 23500 | 188000 |
| 3/15/2021 | 23500 | 0 | 47000 | 0 | 23500 | 0 | 23500 | 0 |
| 3/18/2021 | 211500 | 0 | 56400 | 0 | 23500 | 0 | 23500 | 0 |
| 3/22/2021 | 211500 | 0 | 56400 | 0 | 23500 | 0 | 23500 | 0 |
| 3/29/2021 | 211500 | 0 | 211500 | 0 | 211500 | 0 | 211500 | 0 |
| 4/5/2021 | 211500 | 0 | 211500 | 0 | 211500 | 0 | 211500 | 0 |
| | | | | | | | | |
| **SubTotal** | | **188,000** | | **164,500** | | **211,500** | | **399,500** |
| **SubTotal** | | | | | | | | |

**Tank Sub** **963,500**

**Total Water Discharged** **2,722,500**

CWP contact water pond

CWT contact water tank

**Losses:** Does not take into account: incorrect tallying, evaporation

**Fourth Quarter: April 2021 through June 2021(summary of DOE data review)**

The approximated volume for the ponds/tanks/catchment were put into a spreadsheet and if the next week's numbers were lower, they were marked as discharged. The numbers for the next week were subtracted from the previous week to determine how much water was released to the Sediment Basin for that week. The discharged volumes were totaled by Pond/Tank and those volumes were totaled for the total approximated volume discharged for the period. The fourth quarter period was from 4/6/2021 to 6/28/2021. Table 5.2.11 shows the total volume discharged since 4/6/2021. The approximated total water discharged from the Contact Water Ponds for the fourth quarter was 2,708,000 gallons (Table 5.2.12). The approximated total volume of water discharged from the Contact Water Tanks for the fourth quarter was 1,518,100 gallons. With the Cell 6 catchment discharging 50,000 gallons, the total approximated volume of non-stormwater discharged to the Sediment Basin was 4,276,100 gallons for the period from 4/6/2021 ending 6/28/2021 (Table 5.2.13).

Table 5.2.13 shows the total volumes by ponds and tanks for the first, second, third and fourth quarters of Fiscal Year 2021. Water discharged from the ponds totaled 7,437,000 gallons, water from the tanks totaled 4,385,000, and water discharged from the catchment at Cell 6 totaled 190,000 gallons for a total of 12,012,100 gallons of non-stormwater (NSW) discharged to the sediment basin for release to the environment.

Figures 5.2.16 through Figure 5.2.21 convey the amounts of NSW discharged in a graphical format. Figure 5.2.16 depicts the totals of NSW discharged for the fourth quarter of the 2021 fiscal year. Figure 5.2.17 shows the running total of discharged NSW for FY2021. Figure 5.2.18 shows the discharged water volumes for just the four Contact Water Ponds and the Cell 6 catchment. Figure 5.2.19 shows the running total of NSW discharged from the ponds into the sediment basin. Figure 5.2.20 shows the volumes of water originating from the Contact Water Tanks for just the fourth quarter of FY2021. Finally, Figure 5.2.21 shows the running total of water discharged from the Contact Water Tanks for FY2021.

## Table 5.2.11: EMWMF Fourth Quarter FY21 Ponds/Tanks Weekly Approximated Volumes in Gallons

| Date | Cell 6 catchment | CWP #1 | CWP #2 | CWP #3 | CWP #4 | Pond Sub | CWT A | CWT B | CWT C | CWT D | Tank Sub | Total Water Stored |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **4/5/2021** | 80000 | 415000 | 23000 | 373000 | 379000 | **1,190,000** | 211500 | 211500 | 211500 | 211500 | **634,500** | **1,904,500** |
| **4/12/2021** | 80000 | 17000 | 23000 | 6000 | 365000 | **411,000** | 235000 | 47000 | 211500 | 23500 | **282,000** | **773,000** |
| **4/19/2021** | 80000 | 17000 | 23000 | 31000 | 11000 | **82,000** | 211500 | 94000 | 23500 | 23500 | **352,500** | **514,500** |
| **4/26/2021** | 80000 | 17000 | 23000 | 10000 | 3000 | **53,000** | 23500 | 94000 | 23500 | 23500 | **164,500** | **297,500** |
| **5/3/2021** | 80000 | 17000 | 48000 | 10000 | 7000 | **82,000** | 23500 | 94000 | 23500 | 23500 | **164,500** | **326,500** |
| **5/10/2021** | 80000 | 383000 | 443000 | 273000 | 7000 | **1,106,000** | 23500 | 94000 | 23500 | 23500 | **164,500** | **1,350,500** |
| **5/17/2021** | 50000 | 398000 | 443000 | 314000 | 45000 | **1,200,000** | 23500 | 211500 | 131600 | 23500 | **390,100** | **1,640,100** |
| **5/24/2021** | 50000 | 9000 | 23000 | 38000 | 3000 | **73,000** | 23500 | 23500 | 117500 | 23500 | **188,000** | **311,000** |
| **6/1/2021** | 50000 | 17000 | 23000 | 38000 | 3000 | **81,000** | 23500 | 23500 | 117500 | 23500 | **188,000** | **319,000** |
| **6/7/2021** | 50000 | 17000 | 23000 | 31000 | 7000 | **78,000** | 23500 | 23500 | 141000 | 23500 | **211,500** | **339,500** |
| **6/14/2021** | 100000 | 17000 | 48000 | 209000 | 11000 | **285,000** | 23500 | 47000 | 211500 | 70500 | **352,500** | **737,500** |
| **6/21/2021** | 80000 | 41000 | 74000 | 314000 | 26000 | **455,000** | 23500 | 23500 | 23500 | 211500 | **282,000** | **817,000** |
| **6/28/2021** | 80000 | 448000 | 74000 | 373000 | 26000 | **921,000** | 141000 | 94000 | 23500 | 23500 | **282,000** | **1,283,000** |

Pond,Tank or Catchment volume before discharge

CWP - Contact Water Pond

CWT - Contact Water Tank

Losses -Does not take into account: incorrect tallying, evaporation

## Table 5.2.12: Calculated Approximated Volumes Discharged 4/6/2021 to 6/28/2021 in Gallons

| | Cell 6 Catchment | | CWP #1 | | CWP #2 | | CWP #3 | | CWP #4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | |
| 4/5/2021 | 80000 | 0 | 415000 | 0 | 23000 | 420000 | 373000 | 0 | 379000 | 0 | |
| 4/12/2021 | 80000 | 0 | 17000 | 398000 | 23000 | 0 | 6000 | 367000 | 365000 | 14000 | |
| 4/19/2021 | 80000 | 0 | 17000 | 0 | 23000 | 0 | 31000 | 0 | 11000 | 354000 | |
| 4/26/2021 | 80000 | 0 | 17000 | 0 | 23000 | 0 | 10000 | 21000 | 3000 | 8000 | |
| 5/3/2021 | 80000 | 0 | 17000 | 0 | 48000 | 0 | 10000 | 0 | 7000 | 0 | |
| 5/10/2021 | 80000 | 0 | 383000 | 0 | 443000 | 0 | 273000 | 0 | 7000 | 0 | |
| 5/17/2021 | 50000 | 30000 | 398000 | 0 | 443000 | 0 | 314000 | 0 | 45000 | 0 | |
| 5/24/2021 | 50000 | 0 | 398000 | 0 | 23000 | 420000 | 38000 | 276000 | 3000 | 42000 | |
| 6/1/2021 | 50000 | 0 | 398000 | 0 | 23000 | 0 | 38000 | 0 | 3000 | 0 | |
| 6/7/2021 | 50000 | 0 | 398000 | 0 | 23000 | 0 | 31000 | 7000 | 7000 | 0 | |
| 6/14/2021 | 100000 | 0 | 17000 | 381000 | 48000 | 0 | 209000 | 0 | 11000 | 0 | |
| 6/21/2021 | 80000 | 20000 | 41000 | 0 | 74000 | 0 | 31400 | 0 | 26000 | 0 | |
| 6/28/2021 | 80000 | 0 | 448000 | 0 | 74000 | 0 | 373000 | 0 | 26000 | 0 | |
| **SubTotal** | | **50,000** | | **779,000** | | **840,000** | | **671,000** | | **418,000** | |
| **SubTotal** | | **50,000** | | | | | | | | **Pond Sub** | **2,708,000** |

| | CWT A | | CWT B | | CWT C | | CWT D | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | **Meas. Vol.** | **Discharged** | |
| 4/5/2021 | 211500 | 0 | 211500 | 0 | 211500 | 0 | 211500 | 0 | |
| 4/12/2021 | 23500 | 188000 | 47000 | 164500 | 211500 | 0 | 23500 | 188000 | |
| 4/19/2021 | 211500 | 0 | 94000 | 0 | 23500 | 188000 | 23500 | 0 | |
| 4/26/2021 | 23500 | 188000 | 94000 | 0 | 23500 | 0 | 23500 | 0 | |
| 5/3/2021 | 23500 | 0 | 94000 | 0 | 23500 | 0 | 23500 | 0 | |
| 5/10/2021 | 23500 | 0 | 94000 | 0 | 23500 | 0 | 23500 | 0 | |
| 5/17/2021 | 23500 | 0 | 211500 | 0 | 131600 | 0 | 23500 | 0 | |
| 5/24/2021 | 23500 | 0 | 23500 | 188000 | 117500 | 14100 | 23500 | 0 | |
| 6/1/2021 | 23500 | 0 | 23500 | 0 | 117500 | 0 | 23500 | 0 | |
| 6/7/2021 | 23500 | 0 | 23500 | 0 | 141000 | 0 | 23500 | 0 | |
| 6/14/2021 | 23500 | 0 | 47000 | 0 | 211500 | 0 | 70500 | 0 | |
| 6/21/2021 | 23500 | 0 | 23500 | 23500 | 23500 | 188000 | 211500 | 0 | |
| 6/28/2021 | 141000 | 0 | 94000 | 0 | 23500 | 0 | 23500 | 188000 | |
| **SubTotal** | | **376,000** | | **376,000** | | **390,100** | | **376,000** | |
| **SubTotal** | | | | | | | **Tank Sub** | **1,518,100** | **4,276,100** |
| | | | | | | | | | **Total Water Discharged** |

**CWP** Contact water pond

**CWT** Contact water tank

**Losses:** Does not take into account: incorrect tallying, evaporation

**Meas. Vol.** Measured Volume in Gallons

**Table 5.2.13: EMWMF FY21 Ponds/Tanks/Catchment Non-Stormwater Discharged Volumes in Gallons**

| FY21 Quarter | Cell 6 Catchment | Pond Subtotal | Tank Subtotal | Total |
|---|---|---|---|---|
| First | 60,000 | 455,000 | 634,500 | 1,149,500 |
| Second | 40,000 | 2,555,000 | 1,269,000 | 3,864,000 |
| Third | 40,000 | 1,719,000 | 963,500 | 2,722,500 |
| Fourth | 50,000 | 2,708,000 | 1,518,100 | 4,276,100 |
| FY21 Total | 190,000 | 7,437,000 | 4,385,100 | 12,012,100 |

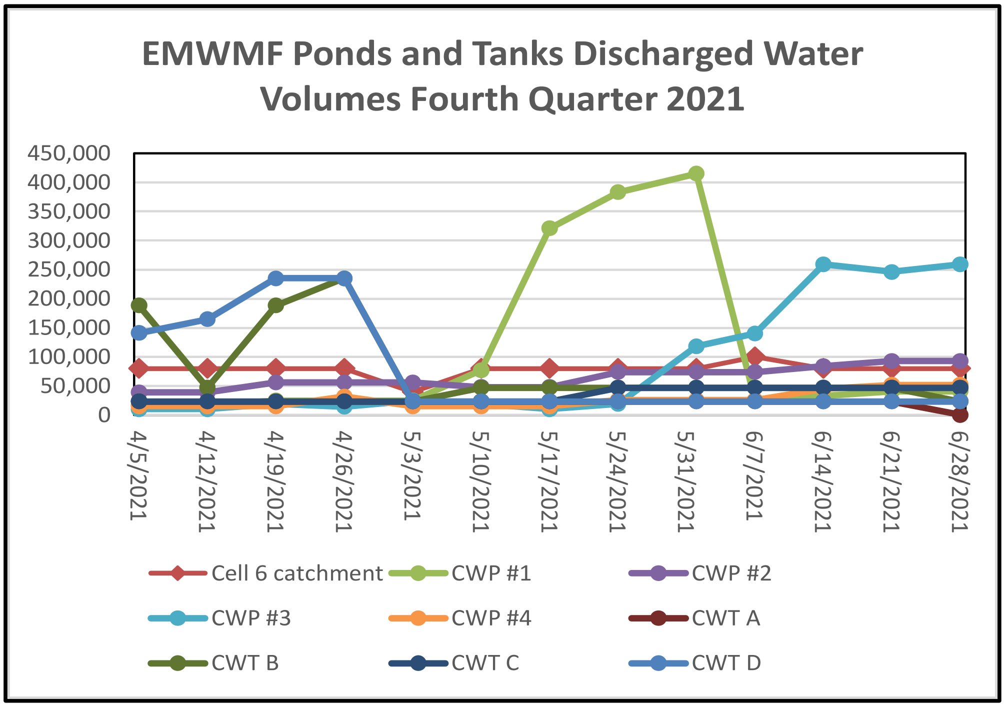



**Figure 5.2.16: EMWMF Discharged Water Volumes Fourth Quarter FY 2021**

De minimus Volume for Ponds is 10k to 17k gallons. De minimus for the tanks is 23.5k gallons

Data from EMWMF Water Management Snapshot provided by DOE for the EMWMF.

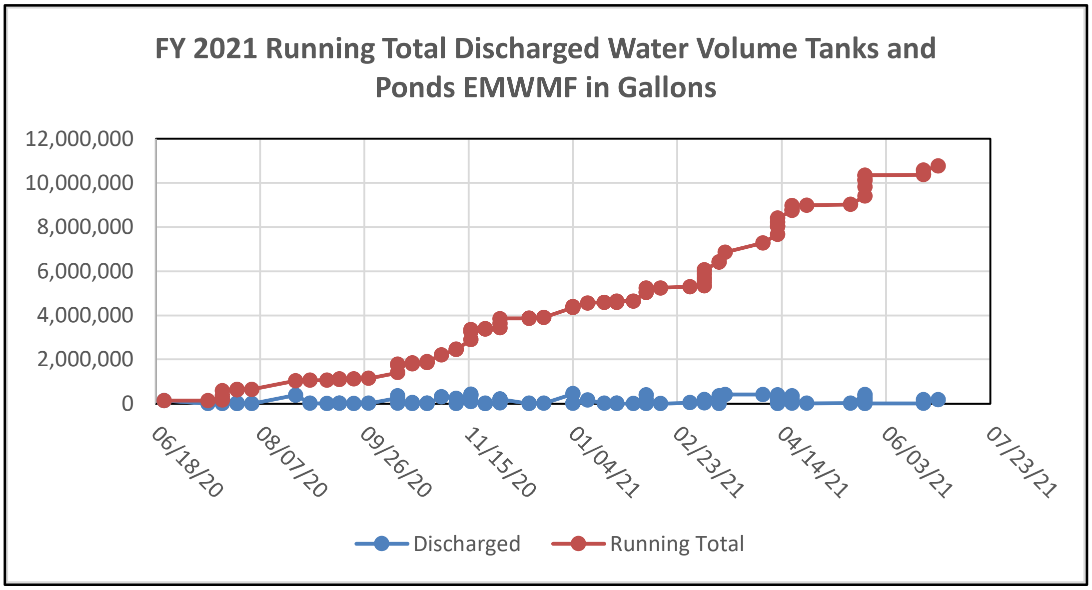



**Figure 5.2.17: Contact Water Tanks and Ponds Running Total of Discharged Water Volume in Gallons**

Data from EMWMF Water Management Snapshot provided by DOE for the EMWMF.

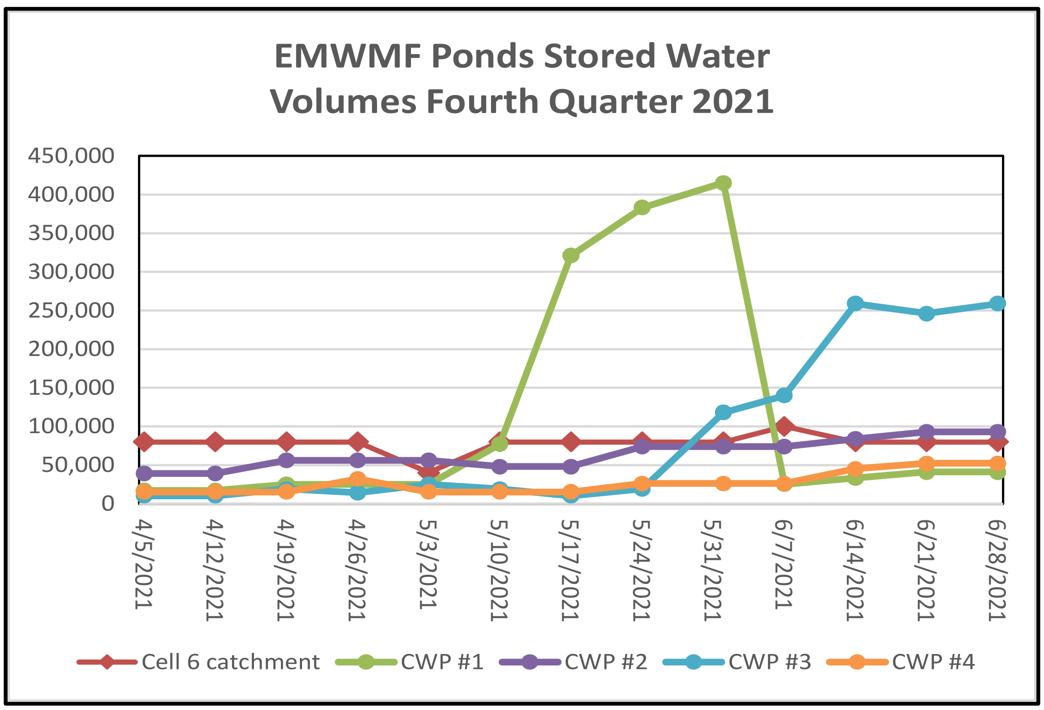



**Figure 5.2.18: EMWMF Ponds Discharged Water Volumes Fourth Quarter FY 2021**

De minimus Volume is 17,000 gallons for pond 1, ~17,000 for Pond 2, 10,000 for Pond 3 and 15,000 for Pond 4

Data from EMWMF Water Management Snapshot provided by DOE for the EMWMF.

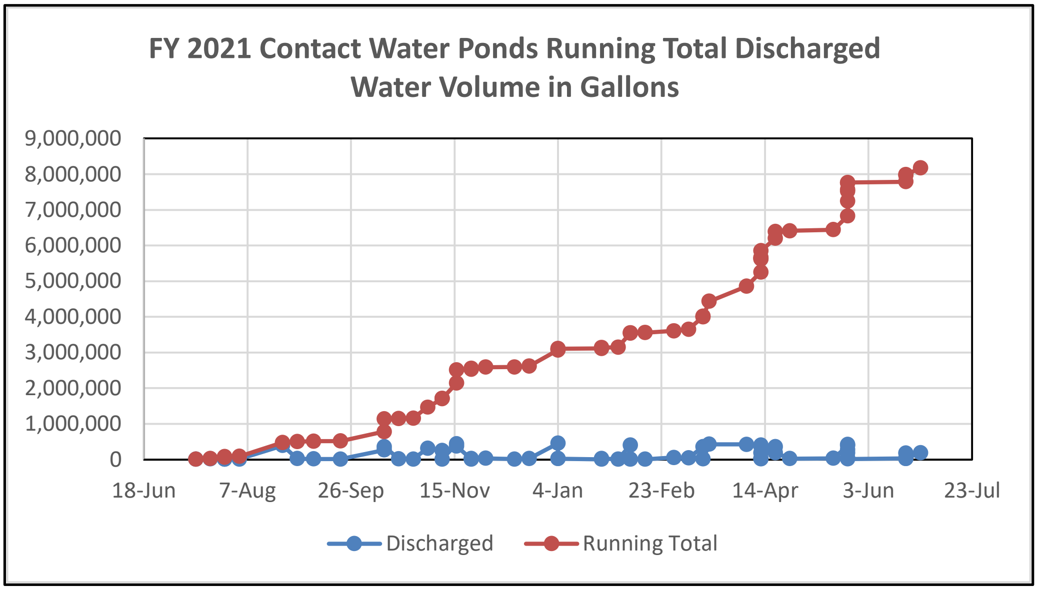



**Figure 5.2.19: Contact Water Ponds Running Total of Discharged Water Volume in Gallons**

Data from EMWMF Water Management Snapshot provided by DOE for the EMWMF.

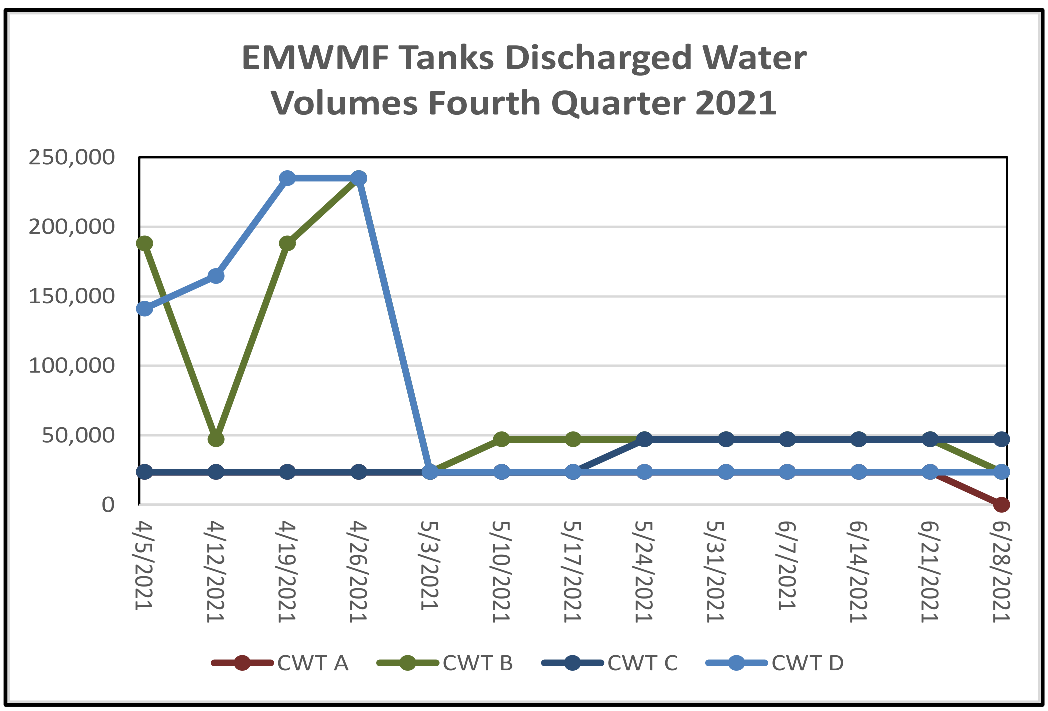



**Figure 5.2.20: EMWMF Tanks Discharged Water Volumes Fourth Quarter FY 2021**

De minimus for Tanks A through D is 23,500 gallons.
Data from EMWMF Water Management Snapshot provided by DOE for the EMWMF.

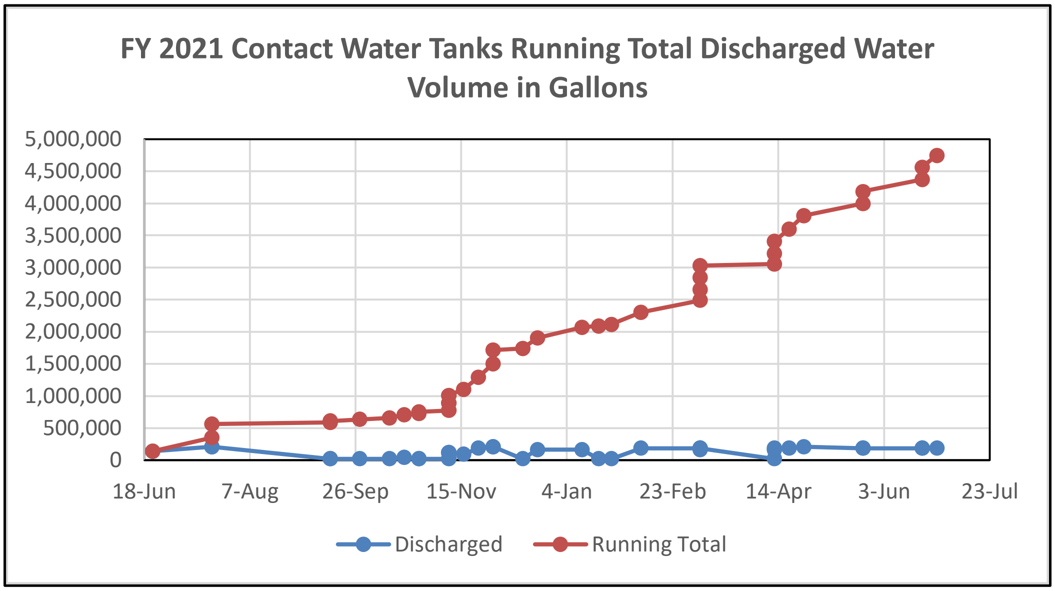



**Figure 5.2.21: Contact Water Tanks Running Total of Discharged Water Volume in Gallons**

Data from EMWMF Water Management Snapshot provided by DOE for the EMWMF.

### DOE Sampling for Hexavalent Chromium ($Cr^{+6}$) Fiscal Year 2021

Table 5.2.14 lists $Cr^{+6}$ results greater than non-detect (ND) as recorded during FY2021. Contact Water Pond #1 (CWP #1) had four samples greater than non-detect, two samples at 8 micrograms/liter and two samples at 7 micrograms/liter. CWP#2 had two samples measuring 11 micrograms/liter. Contact Water Tank D (CWT D) measured 7.5 micrograms/liter of $Cr^{+6}$. The criterion maximum concentration discharge level for hexavalent chromium is 16 micrograms/liter per TDEC Rule 0400-40-03-.03(3)g. The recently received Phased Construction Completion Report for 2020 reported that no $Cr^{+6}$ above the release limit was discharged to the environment. Eight metals, including mercury, and hexavalent chromium are analyzed for along with pesticides, solids, total organic carbon, and radionuclides

## Table 5.2.14: DOE $Cr^{+6}$ Results Greater Than Non-Detect Fiscal Year 2021

| Date | Cell 6 | CWP#1 | CWP#2 | CWP#3 | CWP#4 | CWTA | CWTB | CWTC | CWTD | Leachate Tanks |
|---|---|---|---|---|---|---|---|---|---|---|
| 6/22/2020 | NA | NA | NA | NA | NA | NA | ND | NA | NA | ND |
| 6/29/2020 | NA | NA | NA | NA | NA | NA | ND | NA | NA | ND |
| 7/6/2020 | NA | NA | NA | NA | NA | NA | ND | NA | NA | ND |
| 7/13/2020 | NA | NA | NA | NA | NA | NA | ND | NA | ND | ND |
| 7/20/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 7/27/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 8/3/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 8/10/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 8/17/2020 | NA | ND | NA | NA | NA | NA | NA | NA | NA | ND |
| 8/24/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 8/31/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 9/8/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 9/14/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 9/21/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 9/28/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 10/5/2020 | NA | ND | NA | ND | NA | NA | NA | NA | NA | ND |
| 10/12/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 10/19/2020 | NA | NA | ND | NA | NA | NA | NA | NA | NA | ND |
| 10/26/2020 | NA | NA | ND | NA | NA | NA | NA | NA | NA | ND |
| 11/2/2020 | NA | ND | NA | ND | NA | NA | NA | NA | NA | ND |
| 11/9/2020 | NA | ND | NA | ND | NA | NA | NA | ND | ND | ND |
| 11/16/2020 | NA | NA | NA | NA | NA | NA | ND | NA | NA | ND |
| 11/23/2020 | NA | NA | NA | NA | NA | ND | NA | ND | NA | ND |
| 11/30/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 12/7/2020 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 12/14/2020 | NA | NA | NA | NA | NA | NA | NA | NA | ND | ND |
| 12/21/2020 | NA | NA | NA | NA | NA | NA | NA | NA | ND | ND |
| 12/28/2020 | NA | NA | ND | NA | NA | NA | ND | NA | NA | ND |
| 1/4/2021 | NA | NA | NA | NA | NA | ND | ND | NA | NA | ND |
| 1/11/2021 | NA | NA | NA | NA | NA | ND | NA | NA | NA | ND |
| 1/19/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 1/25/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | - |
| 2/1/2021 | NA | ND | NA | NA | NA | NA | NA | NA | ND | ND |
| 2/8/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 2/15/2021 | NA | NA | NA | NA | NA | NA | NA | ND | NA | ND |
| 2/22/2021 | NA | NA | NA | NA | NA | NA | ND | NA | ND | ND |
| 3/1/2021 | NA | NA | NA | NA | NA | ND | ND | ND | ND | ND |
| 3/8/2021 | NA | ND | NA | ND | NA | NA | NA | NA | NA | ND |
| 3/15/2021 | NA | ND | NA | NA | NA | NA | NA | NA | NA | ND |
| 3/22/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 3/29/2021 | NA | NA | ND | NA | NA | ND | NA | NA | NA | ND |
| 4/5/2021 | NA | 8 | NA | ND | ND | NA | ND | ND | 7.5 | ND |
| 4/12/2021 | NA | NA | NA | NA | ND | ND | NA | ND | NA | ND |
| 4/19/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 4/26/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 5/3/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 5/10/2021 | NA | 7 | 11 | ND | NA | NA | NA | NA | NA | ND |
| 5/17/2021 | NA | 7 | 11 | ND | NA | NA | ND | NA | NA | ND |
| 5/24/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 6/1/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 6/7/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 6/14/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 6/21/2021 | NA | NA | NA | NA | NA | NA | NA | NA | NA | ND |
| 6/28/2021 | NA | 8 | NA | ND | NA | NA | NA | NA | NA | ND |

| | |
|---|---|
| CWP | Contact Water Tank |
| CWT | Contact Water Pond |

**TDEC DoR-OR Sediment Basin Sampling**

No samples were collected in 2020-2021 due to water that continued to be present in the sediment basin and grab sampling was not feasible or safe.

### 5.2.8 Conclusions

The FY2021 TDEC DoR-OR sample results are similar to DOE's results and continue to detect levels of uranium isotopes well below the EPA MCLs. These uranium isotope levels from EMWMF-2 (Underdrain) are increasing very slightly. This sampling station is the first point where contamination from the landfill's waste would be seen if there was a problem with the liner system. EMWMF-3 continues to discharge constituents of concern but not in concentrations that violate the EMWMF Record of Decision discharge limits.

### 5.2.9 Recommendations

DOE samples the effluents at EMWMF-3 weekly on a flow proportional basis. At EMWMF-3, TDEC DoR-OR recommends quarterly sampling and spot sampling based on field observations, to perform continuity checks, and determine if significant levels of contaminants are discharged into Bear Creek. Also, TDEC DoR-OR recommends sampling of contact water ponds/tanks as they are discharged to the unlined ditch at EMWMF-5 and then to the sediment basin.

DOE samples EMWMF-2 bi-monthly. While TDEC DoR-OR also sampled this location bi-monthly, TDEC sampling events were scheduled to occur on months when DOE does not sample. For example, DOE sampled January, March, and May, while DoR-OR sampled February, April and June. The basis for bi-monthly sampling is because EMWMF-2 is the first place that contaminants from the landfill come to the surface and is then discharged to Bear Creek without any treatment. Sampling at EMWMF-2 should be conducted on a regular basis where the requested analytical suite is radionuclides and metals.

### 5.2.10 References

National primary drinking water standards (40 CFR Part 141, National Primary Drinking Water Regulations, Subparts B and G). https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#Radionuclides

Environmental Sampling of the Oak Ridge Reservation and its Environs Quality Assurance Project Plan, Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge: (2015)

Sampling and Analysis Plan for General Environmental Monitoring of the Oak Ridge

Reservation and its Environs, Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge (2016).

Operating Procedure for Surface Water Sampling, SESDPROC-201-R4 US-EPA, Region 4, LSASD, Athens, Georgia (2016)

Quality Systems Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water Revision 5 Tennessee Department of Environment and Conservation, Division of Water Resources, (2018)

Procedures for Shipping Samples to Laboratories for Analysis. Draft SOP No. 101 Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge (2019).

# 6.0 RADIOLOGICAL MONITORING

## 6.1 ENVIRONMENTAL DOSIMETERS

### 6.1.1 Background

Radiation is emitted by various radionuclides that have been produced, stored, and disposed of on the Department of Energy's (DOE) Oak Ridge Reservation (ORR). Associated contaminants and other radiation sources are evident in ORR facilities and surrounding soils, sediments, and waters. In order to independently assess the risks posed by these radioactive contaminants and from other potential sources, the Oak Ridge Office of the Tennessee Department of Environment and Conservation's Division of Remediation (TDEC DoR-OR) began continuous monitoring of ambient radiation levels on and near the vicinity of the ORR in 1995. This project provides:

- Conservative estimates based on continuous monitoring of the potential dose to members of the public from exposure to gamma radiation attributable to DOE activities/facilities on the ORR;
- Baseline values used to assess the need and/or effectiveness of remedial actions;
- Information necessary to establish trends in gamma radiation emissions;
- Information relative to the unplanned release of radioactive contaminants on the ORR.

### 6.1.2 Problem Statements

As environmental cleanup activities progress on the ORR, new temporary radiological waste storage areas are created as well as expanding public access to the ORR. As these changes occur, a concern is if DOE's radiological controls are adequate to protect the public from radiation.

Specific areas of potential radiological dose to the public that may need verification include the following:

- Ongoing demolition activities and the associated radioactive waste storage areas;
- Historically contaminated soils and sediments;
- Current operational activities such as the Spallation Neutron Source.

### 6.1.3 Goals

The goal of the Environmental Dosimeters Project is to maintain independent monitoring of radioactive dose and to monitor DOE's efforts to reduce radiation levels both on and in the vicinity of the ORR. These conditions are expected to improve as remediation activities continue and stored materials are disposed of.

Dosimeters are changed out (new deployed and old retrieved) during a two- to three-day period at the beginning of each quarter (in January, July, and October). Every attempt was made to complete the deployment and retrieval (exchange) in a two to three-day period as soon as possible after receipt from Landauer.

There was one issue that slightly changed the 2020 monitoring. During the spring of 2020, work restrictions from the SARS-Cov2 virus pandemic prevented dosimeters being exchanged for the April event. Arrangements were made with Landauer, such that the dosimeters would be left in place and exchanged in June 2020. This happened and the schedule subsequentially returned to a normal frequency. The dose was calculated by Landauer to cover a 2020 1$^{st}$ and 2$^{nd}$ Quarter combined period. Subsequent to this, exchange continued to the first quarter of 2021 before it was decided to end the dosimeter project. This report includes presentation and interpretation of all data up to the end of the first quarter of 2021, the last data that were collected.

### 6.1.4 Scope

The scope of this project was to independently assess, areas on the ORR, the potential public dose from site specific radiation exposure. The Radiation Monitoring Using Hand-Held Dose Meters and Deployed Dosimeters Project focused on areas of all three Oak Ridge Reservation facilities, as well as background sites in and near Oak Ridge. Emphasis was placed on areas where radioactive materials are stored, processed, or disposed. Areas where radiation levels were particularly of interest to stakeholders, such as the Environmental Management Waste Management Facility (EMWMF) and parts of the East Tennessee Technology Park (ETTP) that are now much more accessible to the public, were also included in this scope. It was important to know where potential problems exist, but it was equally important to inform stakeholders where problems did not exist.

The Radiation Monitoring Using Hand-Held Dose Meters and Deployed Dosimeters Project was conducted on the ORR and at background areas in and around the city of Oak Ridge in order to monitor general radiological dose. Gamma radiation exposure levels were monitored at all sites and neutron radiation was monitored at select sites.

During late 2019 the total number of dosimeters used was reduced from 144 to 25. The reduction was based upon the previous several years' results where many locations consistently showed values below or well below the control level used by Landauer in reports (20 mrem) or at elevated sites that demonstrated clear steady downward trends. A factor that played into this was that DOE and its contractors were demolishing or have demolished many buildings. For example, at ETTP, rates should trend to lower values. However, some locations have concrete slabs and other structures that contain contaminated soils beneath the slabs and when these structures are removed, dose rates might well increase and require further monitoring.

Instead of monitoring the remaining 119 sites, if necessary, a hand-held dose rate meter and other instruments were to be used to measure dose and the current radioactivity, based upon the nature of the location and the role of the site. The combination of hand-held measurements and remaining deployed dosimeters took the place of dosimeters deployed at all previously monitored sites. This added flexibility to the monitoring in locations where DOE and its contractors move materials around or change storage as they need to. Since then, the dosimeter deployment has ceased – so only, when necessary, will measurement using hand-held instruments be done in the future.

### 6.1.5 Methods, Materials, Metrics

All work on the Environmental Dosimeters Project was conducted under the guidance of TDEC DoR-OR's 2020 Health and Safety Plan (TDEC, 2020). In this effort, environmental dosimeters were used to measure the gamma radiation dose attributable to external radiation at selected monitoring stations. Results were compared to background values and to the State's primary dose limit for members of the public.

Dosimeters are currently deployed at the ORNL Main Campus in Bethel Valley, in Melton Valley, at the Spallation Neutron Source at ORNL, on the ORAU South Campus, in the City of Oak Ridge and its vicinity, and at Fort Loudon dam (the latter two are background locations).

Dosimeters were previously distributed in select areas of Y-12, at EMWMF, the ORNL Tower Shielding and Cesium Forest areas, and at ETTP. Since the reduction in the number of dosimeters being used changed from 144 to 25, many of these areas without dosimeters were only to be monitored using hand-held instruments on an as-needed basis. ETTP was no longer being monitored with dosimeters.

Optically Stimulated Luminescence Dosimeters (OSLs) were used for the project due to their superior sensitivity compared to Thermoluminescence Dosimeters (TLDs) (Boons, Van Iersel, & Genicot, 2012). The majority of the areas were monitored with only gamma detecting dosimeters, whereas areas with the potential for neutron fluxes were also monitored with neutron-detecting dosimeters. OSLs are more sensitive than TLDs and they will record levels of exposure as low as 1 mrem vs. the 10 mrem of the TLDs. The dosimeters were purchased from Landauer, Inc. in Glenwood, Illinois.

Dosimeters at all sites were changed out by TDEC DoR-OR and analyzed (by Landauer, Inc.) on a quarterly schedule during the months of January, July, and October. A total of 25 dosimeters were deployed/retrieved during each quarter (new ones placed in the field; those in the field returned for processing).

Dosimeters were received from Landauer, Inc. during the first weeks of January, July, and October. Upon receipt, the dosimeters were logged in (to ascertain that all units were received) and prepared for deployment to the various sites. At some of the sites, TDEC DoR-OR staff contacted site personnel to arrange for access for the deployment. At certain sites, the TDEC DoR-OR staff were accompanied by site personnel during the deployment, at others, gate keys were borrowed to gain access to the areas.

Every attempt was made to complete the task within two to three days (a maximum of one week) of receiving the dosimeters. Much of this depended on the schedules of DOE and Contractor personnel who were site contacts, weather conditions, and other extenuating circumstances (e.g., temporary inability to access certain areas because of ongoing site activities).

After dosimeters were exchanged, those that were destined for analysis were logged back in to determine if any were missing. The dosimeters were then packaged for shipment to Landauer, Inc. for processing. Packages were shipped via ground delivery to avoid the packages being x-rayed in transit (packages shipped via air are likely to be x-rayed; x-raying will impact dose readings and make the data unusable).

After the dosimeters had been analyzed at Landauer, Inc., data files were downloaded, transferred to Excel spreadsheet format, and then placed in a table or graphical plots to be used in the annual Environmental Monitoring Report (EMR).

### 6.1.6 Deviations from the Plan

As previously stated, the total number of dosimeters deployed in the new (2020) plan was 23 and with two off-site dosimeters to monitor background levels (City of Oak Ridge and Fort Loudon Dam). The project was ended at the end of the third quarter of 2021. The fourth quarter results were estimated by averaging the previous three quarters to determine an estimation of the yearly dose total.

## 6.1.7 Results and Analysis

Table 6.1.1 shows the data from 2020 – 2021. In one location the EMWMF, a hand-held survey was completed. The outcome is summarized below in the section that follows labelled: *Additional Results*.

**Table 6.1.1: 2020 – 2021 Data**

**Table 1. 2020-2021 Results for TDEC monitoring on the Oak Ridge Reservation using Environmental Dosimetry**

| Location<br>*Optically Stimulated Luminescent Dosimeter (OSLs) are reported quarterly & neutron dosimeters are reported semi-annually* | Type of Radiation | Dose Reported for 2020-2021 in mrem<br>*M = Below Minimum Reportable Quantity* | | | | 2021 Total Dose ** | 2020 Total Dose ** |
|---|---|---|---|---|---|---|---|
| | | 1st Quarter | 2nd Quarter | 3rd Quarter (2021) | 4th Quarter (2021)* | | |
| Loudoun Dam Air Monitoring Station (Background) | Gamma | 4 | 2 | 2 | 3 | 8 | 12 |
| | Neutron | M | M | M | M | 0 | M |
| White Oak Dam @ Highway 95 | Gamma | 4 | M | M | 1 | 4 | 20 |
| Scarboro Perimeter Air Monitoring Station | Gamma | M | 2 | 4 | 2 | 6 | 26 |
| ORAU Pumphouse Road | Gamma | 9 | 5 | 5 | 6 | 19 | 19 |
| | Neutron | M | M | M | 0 | 0 | M |
| North side of Central Ave. | Gamma | 25 | 23 | 26 | 25 | 74 | 108 |
| Building 3038 Northside | Gamma | 47 | 58 | 46 | 50 | 151 | 235 |
| Building 3607 Materials Storage Area | Gamma | 1214 | 2299 | 2056 | 1856 | 5569 | 11560 |
| TH4 Tank | Gamma | 14 | 16 | 8 | 13 | 38 | 52 |
| Building 3618 | Gamma | 60 | 59 | 52 | 57 | 171 | 202 |
| Hot Storage Garden (3597) | Gamma | 1014 | 1215 | 1037 | 1089 | 3266 | 4396 |
| Neutralization Plant | Gamma | 273 | 122 | 25 | 140 | 420 | 1320 |
| White Oak Creek Weir @ Lagoon Rd | Gamma | 26 | 24 | 18 | 23 | 68 | 107 |
| Cask Storage Containment Area | Gamma | 1147 | 60 | 50 | 419 | 1257 | 5367 |
| Melton Valley Haul Road near creek | Gamma | 137 | 159 | 82 | 126 | 378 | 582 |
| New Hydrofracture Facility | Gamma | 94 | 119 | 113 | 109 | 326 | 421 |
| Confluence of White Oak Ck & Melton Branch | Gamma | 94 | 98 | 80 | 91 | 272 | 360 |
| SWSA 5 TRU Waste Trench | Gamma | 26 | 28 | 23 | 26 | 77 | 113 |
| SWSA 5 Near Storage Tank Area | Gamma | 15 | 13 | 11 | 13 | 39 | 101 |
| | Neutron | M | M | M | 0 | 0 | M |
| Homogeneous Reactor Experiment Site | Gamma | 5 | M | 3 | 3 | 8 | 11 |
| High Flux Isotope Reactor | Gamma | 7 | 6 | 4 | 6 | 17 | 31 |
| Molten Salt Reactor Experiment | Gamma | 13 | 10 | 7 | 10 | 30 | 40 |
| Haw Ridge at Melton Valley Access Road | Gamma | 38 | 38 | 34 | 37 | 110 | 145 |
| SNS Central Exhaust Facility | Gamma | 173 | 79 | 88 | 113 | 340 | 737 |
| | Neutron | M | M | M | 0 | 0 | M |
| SNS LINAC Beam Tunnel Berm West (#1) | Gamma | 10 | 8 | 7 | 8 | 25 | 40 |
| | Neutron | M | M | M | 0 | 0 | M |
| SNS Target Bldg East | Gamma | 9 | 9 | 4 | 7 | 22 | 14 |
| | Neutron | M | M | M | 0 | 0 | M |

Notes: Two types of dosimeters are used in the program, optically stimulated luminescent dosimeters (OSLs) and neutron dosimeters. The OSLs measure the dose from gamma radiation, which is considered sufficient for most of the monitoring stations. The neutron dosimeters, which have been placed at selected locations, measure the dose from neutrons in addition to the gamma radiation. At the locations where the neutron dosimeters have been deployed, the total dose is the sum of the doses reported for neutrons and the dose reported for gamma radiation.

The primary dose limit for members of the public specified in both DOE Orders and 10 CFR Part 20 (Standards for Protection Against Radiation) is 100 mrem total effective dose equivalent in a year, exclusive of the dose contributions from background radiation, any medical administration the individual has received, or voluntary participation in medical research programs. The NRC limit for a decommissioned facility is 25 mrem/yr.

NEW = Data for the period does not exist as this station is new.

M = Below minimum reportable quantity (1 mrem for gamma, 10 mrem for thermal neutrons)

NA = Not analyzed (not deployed at location or Landauer lost).

Absent = The dosimeter was not found at the time of collection.

Damaged = The dosimeter was physically damaged, and the results were not consistent with historical values.

*The dose reported for this quarter is based on the average of the three previous quarters to established estimted yearly doses.

**A control dosimeter is provided with each batch of dosimeters received from the vender. The control dosimeters are used to identify the portion of the dose reported due to radiation exposures received in storage and transit. The dose reported for the control dosimeter is subtracted from the dose reported for each field deployed dosimeter.

When compared to the previous year, there were no significant changes in dose rates in the locations being monitored. However, based on monitoring results referenced in Table 6.1.1, eleven (11) locations did exceed 100 mrem/yr. (Schmidt et al, 2006) for 2020-2021. These locations have historically shown elevated values. Some locations may warrant further monitoring for dose but do not directly indicate any exceedance of the 100 mrem/yr, since it's highly unlikely a person would remain in one location.

**Additional Results**:

As mentioned previously one location was subjected to a hand-held instrument survey: the results, written in *Comments* from the TDEC DoR-OR Field Trip Report, are quoted below:

*TDEC DoR-OR staff met with EMWMF DOE/UCOR staff at 13:00 on 12/15/2021 to perform dose rate surveys of the perimeter fences of the waste cells, contact water ponds, and contact water tanks. All dose rates fell within normal background parameters of 3 µrem/hr to 10 µrem/hr. For safety concerns the east by southeast side of the contact water pond fence was not surveyed due to ongoing construction of the sediment removal pad.* (the complete trip report is available on request).

### 6.1.8 Conclusions

The project has provided passively measured conservative dose rates from select sites across the ORR over time. Those data sets shall be collected in a more site-specific focused manner. Future dose rate data will be measured using hand-held instruments which will yield the most up to date dose rates.

### 6.1.9 Recommendations

The Environmental dosimeter project is no longer active and ended with the data collected and reported from the 1st Quarter, 2021.

### 6.1.10 References

Boons, R., M. Van Iersel, and J.L. Genicot. (2012) External and Environmental Radiation Dosimetry with Optically Stimulated Luminescent Detection Device - Developed at the SCK·CEN. World Journal of Nuclear Science and Technology, 2, 6-15 2: 6–15. http://dx.doi.org/10.4236/wjnst.2012.21002.

Schmidt, D.W, K.L. Banovac, J.T. Buckley, D.W. Esh, R.L. Johnson, J.J. Kottan, C.A. McKenney, T.G. McLaughlin, S. Schneider. (2006) Consolidated Decommissioning Guidance, NUREG-1757 2. Retrieved from https://www.nrc.gov/docs/ML0630/ML063000252.pdf

TDEC. Health and Safety Plan Including Related Policies. (2020) Tennessee Department of

Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, Tennessee.

TDEC. Standard Operating Procedure: Environmental Dosimeters Project (Draft) (2018). Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, Tennessee.

## 6.2 Real Time Measurement of Gamma Radiation

### 6.2.1 Background

The K-25 Gaseous Diffusion Plant, now called the East Tennessee Technology Park (ETTP), began operations in World War II as part of the Manhattan Project. Its original mission was to produce uranium, enriched in the uranium-235 isotope (U-235) for use in the first atomic weapons and later to fuel commercial and government-owned reactors. The K-25 plant was permanently shut down in 1987. As a consequence of operational practices and accidental releases, many of the facilities scheduled for decontamination and decommissioning (D&D) at ETTP are contaminated to some degree. Uranium isotopes are the primary contaminants, but technetium-99 and other fission and activation products are also present, due to the periodic processing of recycled uranium obtained from spent nuclear fuel.

The Y-12 Plant was also constructed during World War II to enrich uranium in the U-235 isotope, in this case, by the electromagnetic-separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, to conduct lithium-mercury enrichment operations, to manufacture components for nuclear weapons, to dismantle nuclear weapons, and to store enriched uranium.

Construction of what is now the Oak Ridge National Laboratory (ORNL), originally known as the X-10 Plant, began in 1943. ORNL focused on reactor research and the production of plutonium and other activation and fission products. These products were chemically extracted from uranium, irradiated in ORNL's graphite reactor and later at other ORNL and Hanford reactors. During early operations, leaks and spills were common in the facilities and associated radioactive materials were released from operations as gaseous, liquid, and solid effluents, with little or no treatment (ORAU, 2003).

The EMWMF was constructed in Bear Creek Valley near the Y-12 National Security Complex to dispose of low-level radioactive waste and hazardous waste generated by remedial activities from all three sites on the Oak Ridge Reservation (ORR).

DoR-OR has deployed gamma-radiation exposure monitors, equipped with microprocessor-controlled data loggers, on the ORR since 1996. The data loggers supplement the DoR-OR Environmental Dosimeters project that measures cumulative dose at specific locations quarterly. The Real Time Measurement of Gamma Radiation project tracks gamma exposure rates over time. Exposure rate monitors measure and record gamma radiation levels at predetermined intervals (e.g., minutes) over extended periods of time (months) and provide an exposure rate profile that can be correlated with activities and or changing conditions.

### 6.2.2 Problem Statements

The Real Time Monitoring of Gamma Radiation project on the Oak Ridge Reservation measures exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods of time. Facilities on the ORR have been known to release variable amounts of gamma radiation, and there is the potential for an unplanned release of gamma emitting radionuclides.

### 6.2.3 Goals

The results from monitored sites are compared to:

- The State of Tennessee (State) limit for the maximum dose to an unrestricted area (2 mrem in any one-hour period).
- State and DOE primary dose limits for members of the public (100 mrem/year).

### 6.2.4 Scope

Candidate monitoring locations for the placement of gamma radiation monitoring instrumentation include sites undergoing remedial activities, waste disposal operations, pre- and post-operational site investigations, and areas of environmental response activities. Anomalous results from DoR-OR's Environmental Dosimeters project may warrant conducting additional gamma radiation monitoring at other locations. Figure 6.2.1 shows the FY2021 sampling locations. Data recorded by the gamma monitors was evaluated by comparing the data to background gamma exposure rates. The data was also compared to the State maximum dose limits and to State and DOE primary dose limits (listed above). For FY2021, gamma exposure rate monitors were located at the following locations:

1. Fort Loudoun Dam (Background Site)
2. Environmental Management Waste Management Facility (EMWMF) Portal Monitor
3. ORNL 3000 area/Central Campus Remediation/former building 3026 Radioisotope Development Laboratory

4. ORNL Molten Salt Reactor Experiment (MSRE)

5. ORNL Spallation Neutron Source (SNS) stack

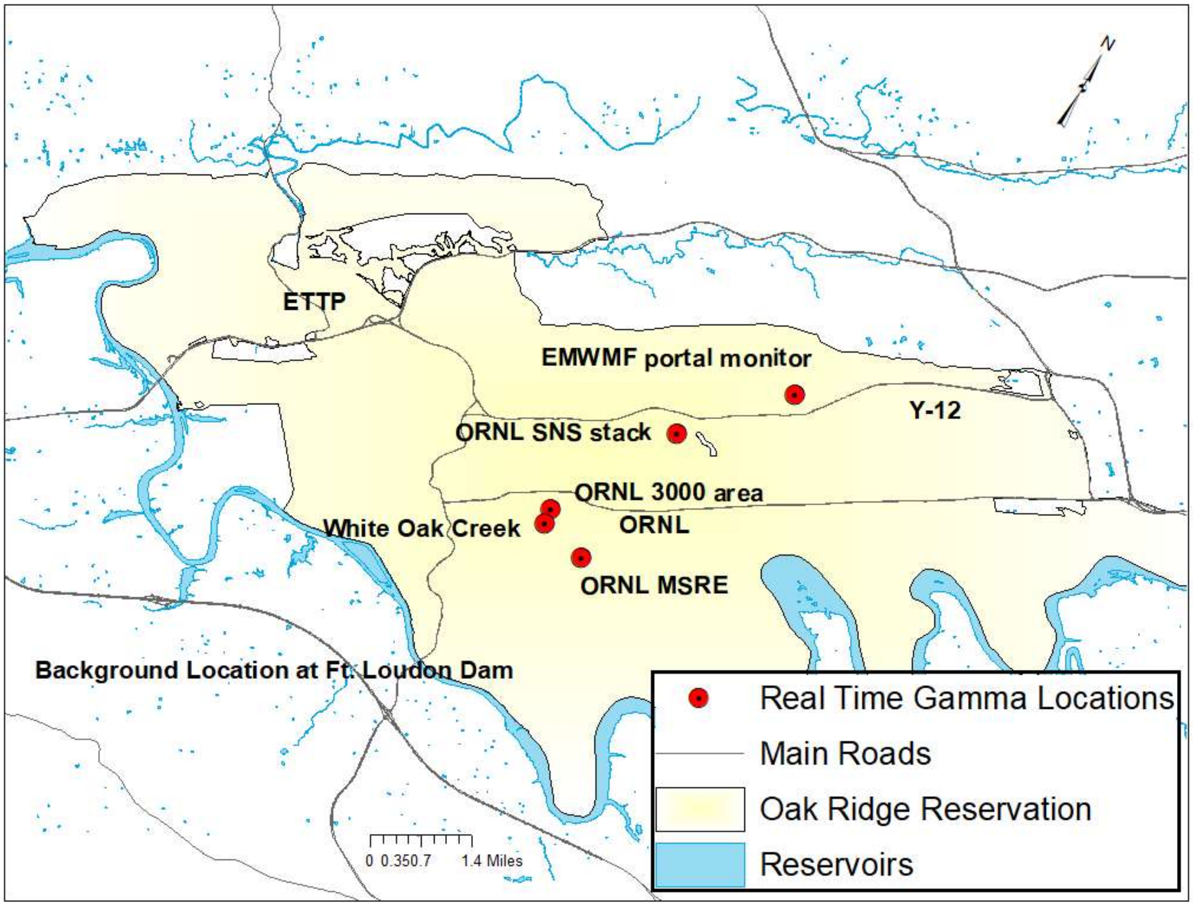



**Figure 6.2.1: Gamma Monitor Locations**

### 6.2.5 Methods, Materials, Metrics

The gamma exposure rate monitors deployed for the DoR-OR Real-Time Measurement of Gamma Radiation project on the Oak Ridge Reservation, are manufactured by Genitron Instruments and are marketed under the trade name GammaTRACER®. Each unit contains two Geiger-Muller tubes, a microprocessor-controlled data logger, and lithium batteries sealed in a weather-resistant case to protect the internal components. The instruments can be programmed to measure gamma exposure rates from one µrem/hour to one rem/hour at predetermined intervals from one minute to two hours. The results reported are the average of the measurements recorded by the two Geiger-Muller detectors. The data for any interval from each detector can be accessed. The results recorded by the data loggers were downloaded to a computer by DoR-OR personnel using an infrared transceiver and associated software.

### 6.2.6 Deviations from the Plan

The instruments were removed from service and returned to the factory for maintenance on 1/6/2021. Therefore, no data is available from that date through the end of the FY2021.

The monitoring instrument that had been at White Oak Creek stopped functioning near the beginning of FY2021. No replacement was available.

### 6.2.7 Results and Analysis

**Fort Loudoun Dam Background**

To better assess exposure rates measured on the ORR and the influence that natural conditions have on these rates, DoR-OR maintains one gamma monitor at Fort Loudoun Dam in Loudon County to collect background information. During the interval 07/01/2020 through 01/06/2021, exposure rates averaged 9.05 μrem/hour and ranged from 7 to 15 μrem/hour, which is equivalent to a dose of approximately 79.3 mrem/year.

**Environmental Management Waste Management Facility**

The EMWMF was constructed in Bear Creek Valley (west of Y-12) to dispose of wastes generated by CERCLA activities on the ORR.

DoR-OR has a gamma monitor acting as a portal monitor at the check-in station for trucks transporting waste into the EMWMF for disposal. Trucks, entering the facility, pass the gamma radiation detector allowing the monitor to detect any gamma radiation-emitting materials that have passed on the way to disposal at the waste cells. This monitoring system allows for the assessment of gamma exposure rates at the monitoring detector over a defined time period and can be used to corroborate DOE’s reporting system that excessive amounts of radiation-emitting materials have not inadvertently passed the monitoring point to be disposed of in the EMWMF facility.

During the interval (07/01/2020 through 01/06/2021), exposure rates averaged 6.9 μrem/hour and ranged from 4 to 12 μrem/hour, similar to the background measurements collected during the same period at Fort Loudoun Dam and seen in Figure 6.2.2.

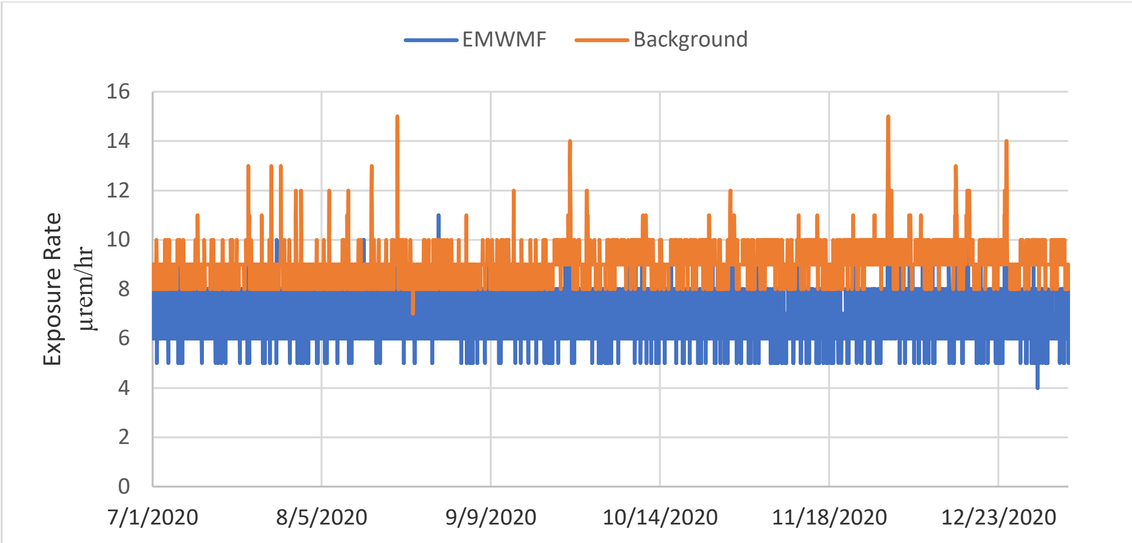



**Figure 6.2.2 EMWMF Gamma Exposure Rates**

**ORNL Central Campus Remediation/Building 3026 Radioisotope Development Laboratory**

Due to the nature of past activities at ORNL, concerns include potential radiological releases during the demolition of high-risk facilities centrally located on ORNL's main campus in close proximity to pedestrian and vehicular traffic.

During the sampling interval (07/01/201 through 01/06/2021), gamma radiation measured at this ORNL site ranged from 9 to 21 µrem/hour and averaged 12.19 µrem/hour (Figure 6.2.3).

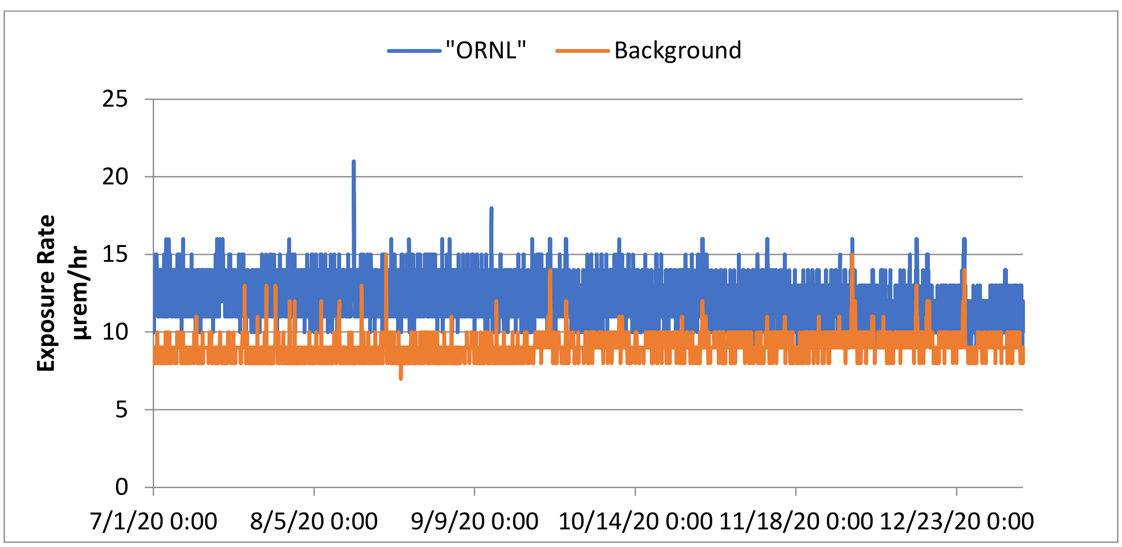



**Figure 6.2.3: ORNL Central Campus Gamma Exposure Rates**

### The Molten Salt Reactor Experiment

During the sampling interval (07/01/2020 through 01/06/2021) monitoring period, exposure rates ranged from 9 to 19 µrem/hour and averaged 12.39 µrem/hour (Figure 6.2.4). The major source of the measured gamma radiation dose above background is assumed to result from a salt probe being temporarily stored in the radiation area, adjacent to the monitoring station.

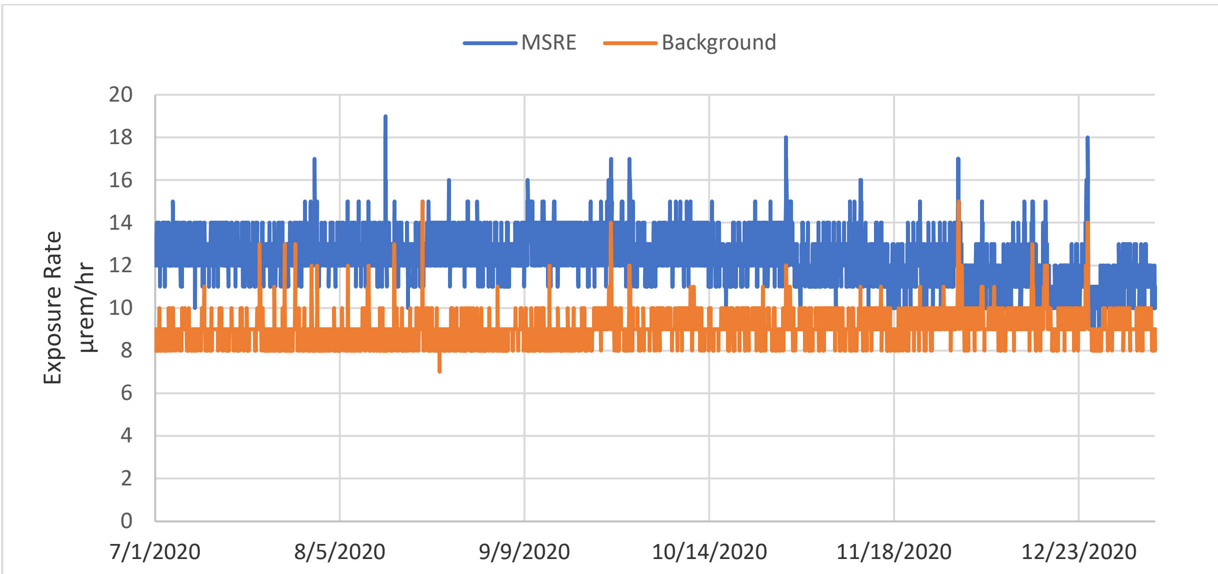



**Figure 6.2.4: Gamma Exposure Rate at Molten Salt Reactor Experiment**

### Spallation Neutron Source

To assess the gamma component of air releases from the Spallation Neutron Source (SNS), DoR-OR's exposure rate monitor is located on the central exhaust stack used to vent air from process areas inside the linear accelerator (linac) and sample target building. The exposure rates vary based on the operational status of the accelerator. During periods when the accelerator is not online, the rates are similar to background measurements. However, much higher levels are recorded during operational periods. The exposure rates measured throughout the sampling period (07/01/2020 through 01/06/2021), ranged from 7 to 3976 µrem/hour and averaged 172 µrem/hour (Figure 6.2.5). For contextual purposes, the exposure rate of 172 µrem/hour would exceed both State and DOE limits of 100 mrem within one year. However, this location is not accessible to the public.

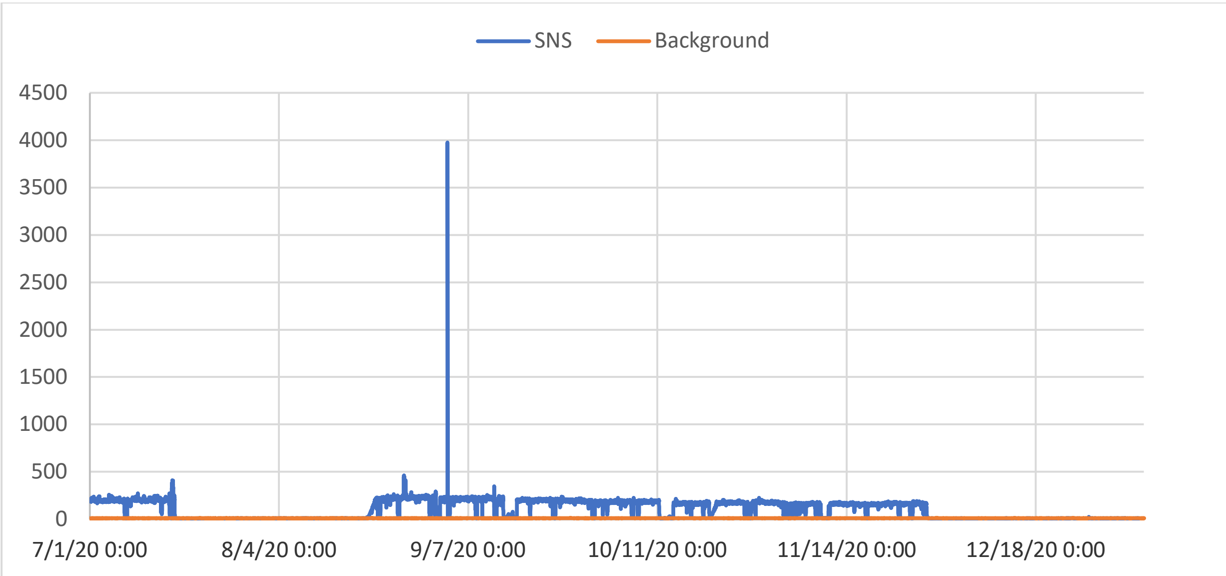



**Figure 6.2.5: Spallation Neutron Source (μrem/hour)**

### 6.2.8 Conclusions

The following conclusions are drawn, based on the data collected from 07/01/2020 through 01/06/2021 at the gamma monitoring locations covered in this report:

- No monitored location exceeded the 2 mrem in any one-hour period.
- No monitored location exceeded the 100 mrem /year limit for members of the public.

### 6.2.9 Recommendations

- TDEC DoR-OR proposes to review the current monitoring locations and make modifications according to DOE activities on the ORR.
- As DOE does not have a similar monitoring program, TDEC DoR-OR proposes to continue this program.

### 6.2.10 References

NRC Dose Limits (from 10 CFR Part 20)

## 6.3 SURPLUS SALES VERIFICATION

### 6.3.1 Background

The Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge Office (TDEC DoR-OR), in an oversight capacity of the U.S. Department of Energy (DOE) and its contractors, conducts radiological surveys of surplus materials originating from the Oak Ridge Reservation (ORR), which are designated for sale to the public. In addition to performing the surveys, the office reviews the procedures used for release of materials under DOE radiological regulations. DOE currently operates their surplus materials release program under DOE Order 458.1 Admin Chg 3, *Radiation Protection of the Public and the Environment*.

Some materials, such as scrap metal, may be sold to the public under annual sales contracts, whereas other materials are staged at various sites around the ORR awaiting auction, i.e., sale. Practices have changed over time at both the Y-12 National Security Complex (Y-12) and at the Oak Ridge National Laboratory (ORNL) regarding surplus sales. With rare exceptions, materials are no longer sold directly to the public by either facility. Materials from ETTP may be released through ORNL Property Excessing. Y-12 now uses an out-of-state contractor to handle the majority of their sales and ORNL focuses their resale operations currently to nine or ten organizations that are approved to bid on sales of materials by the truckload.

At the request of ORNL and/or Y-12 Property Excessing staff, TDEC DoR-OR conducts supplemental radiological verification screening surveys to help ensure that no potentially contaminated materials reach the public. Direct readings are converted to dpm/100 $cm^2$ (dpm = disintegrations per minute) and reported. In the event that elevated radiological activity is detected above the removable contamination limits set forth in NUREG-1757, Volume 1, Revision 2, Section 15.11.1.1 *Release of Solid Materials with Surface Residual Radioactivity* (Schmidt et al., 2006) or *Reg. Guide 1.86*, a quality control check is made with a second meter. If both meters show elevated activity, TDEC DoR-OR immediately reports the finding(s) to the DOE surplus sales program supervisor. A removable contamination assessment may be performed. TDEC DoR-OR then follows the response of the sales organizations to confirm that appropriate steps (i.e., removal of items from sale, resurveys, etc.) are taken to protect the public.

### 6.3.2 Problem Statements

Although the procedure for surplus of materials from the ORR has changed (materials are no longer directly auctioned to the public) the potential for items being released to pre-approved bidders may potentially reach the public.

Even when items of concern are found, they may not ultimately prove to be problematic. What first appears as an item with surface contamination may (with a resurvey) prove to be an instance where the suspected contamination can no longer be detected, is non-reportable daughter products, or naturally occurring radioactive material.

### 6.3.3 Goals

TDEC DoR-OR's intent is to verify that materials that have been staged for sale at ORNL's 115 Union Valley Road Property Excessing Facility or other locations are released in compliance with DOE's release policy. The project attempts to locate any contaminated items that may have evaded detection prior to being staged for sale. In rare instances where items of concern are found, it prevents the release of potentially contaminated materials to the public.

### 6.3.4 Scope

TDEC DoR-OR staff performed pre-auction verification surveys on items being auctioned by ORNL's Excess Properties Sales. These surveys were performed at the request of ORNL's Excess Properties staff per the ESOA Grant, as an additional check before release to the public. When a request was received, every attempt was made to fulfill that request. Typically, no more than eight events occurred during a calendar year.

### 6.3.5 Methods, Materials, Metrics

Surplus sales verification work was performed under the guidance of *TDEC DoR-OR's 2017 Health and Safety Plan* (TDEC 2017) and other references below. Prior to sales of surplus items being released to the public, TDEC DoR-OR (when requested) conducted a pre-auction survey. The intent of this survey was to spot check items that are for sale with appropriate radiation survey instruments in order to ensure that no radioactively contaminated items were released to the public. Not all items or surfaces of a specific item were surveyed for potential radioactive contamination. Specific attention was paid to well-used items where material damage, uncleanliness, or staining was present. However, clean looking items may also be checked. When activity (alpha or beta/gamma) above the removable contamination limit was detected, the item was brought to the attention of Excess Property staff.

Based on TDEC DoR-OR's survey results, the Excess Property staff decided whether or not to have the item rechecked by ORNL RADCON. TDEC DoR-OR did not attempt to determine if a particular item met DOE release criteria but did try to locate items where, there was a potential for the item not meeting unrestricted release criteria set forth by the State of Tennessee, Division of Radiological Health.

### 6.3.6 Deviations from the Plan

There were no deviations from the plan.

### 6.3.7 Results and Analysis

The office responded to a total of four Surplus Sales Survey requests from July 2020 to June 2021. During these visits a total of 12 items were identified with activity above the ambient background. Most of these are TV displays, or equipment that contains ceramics with potassium-40 ($^{40}K$) activity or are HVAC components. In each case, these items were not only initially scanned by ORNL staff, but some had smear samples collected (obvious from the markings on the equipment). The TDEC DoR-OR survey results were shared with ORNL in an e-mail message and the trip report was written and uploaded to DoRWay.

### 6.3.8 Conclusions

The independent Surplus Sales Verification Project performed by TDEC DoR-OR is useful as a final check of equipment and material that will be transferred or sold to the general public. All of the Lots are adequately scanned, but there were some pieces with surface areas where either the alpha or beta activity exceeded the ambient background. These surveys assist DOE in deciding whether equipment meets release criteria.

### 6.3.9 Recommendations

It is recommended that the Surplus Sales Verification Project continue; the project is functional and useful and provides a way for DOE to have an independent survey to confirm their own work. It also allows TDEC DoR-OR staff to become conversant with measuring radioactivity using the proper methods.

### 6.3.10 References


FRMAC Monitoring and Sampling Manual, Vols. 1 & 2. (2012) DOE/NV/11718-181-Vol. 1 & Vol. 2. Federal Radiological Monitoring and Assessment Center, National Nuclear Security Administration. Nevada Test Site.

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2224 (-1) and 43-93 Probe (Dual Phosphorus Meter) (SOP T-532). 2019.

Tennessee Department of Environment and Conservation (TDEC) ,2017, Division of Remediation, Oak Ridge Office (DoR OR) 2017 Health and Safety Plan Including Related Policies, January 2017. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, Tennessee.

# 7.0 SEDIMENT MONITORING

## 7.1 TRAPPED SEDIMENT (EAST FORK POPLAR CREEK)

### 7.1.1 Background

Sediment is an important part of aquatic ecosystems. Many aquatic organisms depend on sediment for habitat, sustenance, and reproduction. Anthropogenic chemicals and waste materials, such as metals, radionuclides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals that are introduced into aquatic systems often accumulate in sediments. Contaminants may accumulate in sediments such that their concentrations are higher than in the water column. Some sediment contaminants may be directly toxic to benthic organisms or may bioaccumulate in the food chain, creating health risks for wildlife and humans. Sediment analysis is an important aspect of environmental quality and impact assessment for rivers, streams, and lakes.

Sediment samples were collected at East Fork Poplar Creek kilometer 23.4 (EFK 23.4). Mill Branch is a tributary of East Fork Poplar Creek and is used as a background stream (Table 7.1.1). Figure 7.1.1 shows the locations of all the TDEC DoR-OR sediment traps, but this report only pertains to EFK 23.4 and Mill Branch kilometer 1.6 (MBK 1.6). Other sampling locations are covered as part of the Bear Creek Assessment Project holistic watershed assessment discussed in section 10.1. Samples were analyzed for radiological activity and metals. Past sediment sampling activities by the Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (DoR-OR) have shown that East Fork Poplar Creek has elevated levels of mercury in sediments. This mercury can be attributed to historical discharges from Y-12.

### 7.1.2 Problem Statements

ORR exit pathway streams are subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These contaminant releases have been detrimental to stream health in the past and present. Identified issues include:

- East Fork Poplar Creek is believed to contribute approximately 0.2 metric tons of mercury to the Clinch River each year. (DOE, 1992)
- Besides mercury, other metals that have been found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver and zirconium. (DOE, 1992)
- Water supply facilities, serving an estimated population of 200,000 persons on the

Tennessee River downstream of White Oak Creek, have the potential of being influenced by streams that drain the ORR. (DOE, 1992)

### 7.1.3 Goals

- Determine stream health through sampling and analysis of suspended sediment.
- Assess site remediation efforts through long-term monitoring of suspended sediment.
- Identify trends in data, based on findings, and use those trends to make recommendations in order to improve sediment quality and the health of affected streams.

### 7.1.4 Scope

This project evaluated the concentrations of potential contaminants in suspended sediments that were being transported in East Fork Poplar Creek (EFPC) by utilizing passive sediment collectors. This project did not have a comparable DOE counterpart, so it provided independent data which assisted in the evaluation of the streams that drain the ORR.

### 7.1.5 Methods, Materials, Metrics

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed in EFPC at EFK 23.4 and at Mill Branch kilometer 1.6 (MBK 1.6). Mill Branch is a tributary of EFPC and is used for background data. Samples were retrieved from the sediment traps at scheduled intervals throughout the year. The sediment traps were deployed on 9/20/2020 and sampled on 2/22/2021 and 6/14/2021.

Sediment samples were analyzed for metals (arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, and uranium) and radiological parameters (gross alpha, gross beta, gamma-emitting radionuclides, strontium-89/90, and uranium (U) isotopes). The metals data were compared to the Consensus-Based Sediment Quality Guidelines (CBSQGs) (MacDonald et al., 2000). Radiological data were compared to data from background locations.

The standard operating protocol used for this project is the TDEC DoR-OR Standard Operating Procedure for Sediment Trap Sampling (TDEC DoR-OR 2017). Suspended sediment samples were collected using fixed sediment collection devices (traps). Sediment traps were installed in stream beds and positioned to accommodate the most considerable flow through the body of the trap. Suitable sites are limited in a stream; careful consideration must be given to the selection of installation locations for the sediment traps. To completely immerse the sediment traps, water flow and depth must be sufficient.

Following a collection period (a minimum of four months), the collected sediment was emptied from a sediment trap and was transferred to a clean bucket where the sediment was allowed to settle on ice from 24 to 48 hours. After the sediment had settled, the supernatant water was carefully drawn off from the sample with a peristaltic pump. Sediment samples were spooned from the bucket into sample containers of appropriate size and construction for the requested analyses.

**Table 7.1.1: Sampling Location Descriptions**

| Sampling Location | DWR ID | Alt. ID | Sampling Rationale | Latitude | Longitude |
|---|---|---|---|---|---|
| East Fork Poplar Creek km 23.4 | EFPOP014.5AN | EFK 23.4 | Surveillance of suspended sediment at point where EFPC leaves DOE property. | 35.99596 | -84.24004 |
| Mill Branch Mile km 1.6 | FECO67I12 | MBK 1.6 | Surveillance of suspended sediment at a background location. | 35.98886 | -84.28935 |

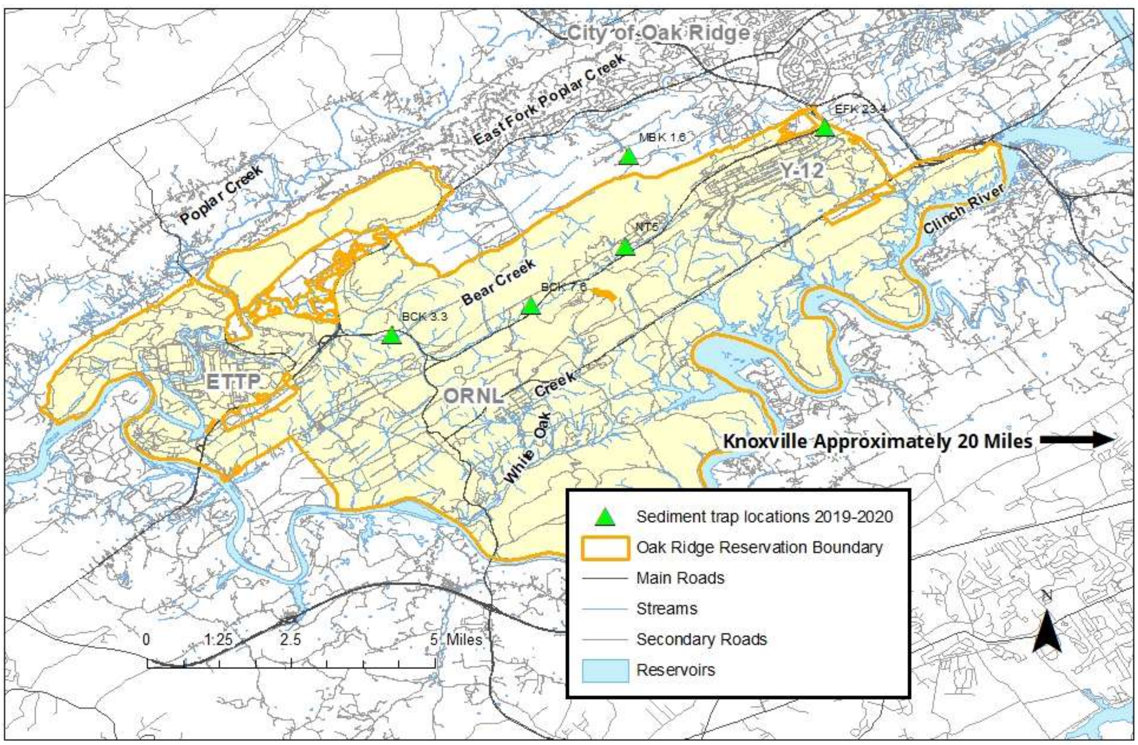



**Figure 7.1.1: Sampling Locations on the ORR**

## 7.1.6 Deviations from the Plan

Sediment trap deployment was delayed from July 2020 to September 11, 2020, due to concerns related to the COVID-19 pandemic. As a result, sampling was delayed until February 2021. This first sampling provided enough sample volume for radiological and metals analyses. The decision to analyze sediments for per- and polyfluoroalkyl substances (PFAS) testing was made after the publication of the Environmental Monitoring Plan (EMP). The second sampling event on June 14, 2021 provided enough sample for organics (semi volatiles, PCBs, PFAS, and pesticides) testing. The organics results have not yet been received from the laboratory.

### 7.1.7 Results and Analysis

Trapped sediment results were compared with the Consensus Based Sediment Quality

Guidelines (CBSQGs) Probable Effects Concentrations (PECs) for each metal. The PECs are CBSQGs that were established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (Ingersoll et al. 2000). Adverse effects, in this case, refer to the effects to benthic macroinvertebrate species only (WDNR 2003). The CBSQGs are considered protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases, in addition to the CBSQGs, other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue-residue guidelines should be used to assess direct toxicity and food chain effects. The threshold effects concentrations (TECs) are concentrations below which adverse effects are not expected to occur (MacDonald et al. 2000).

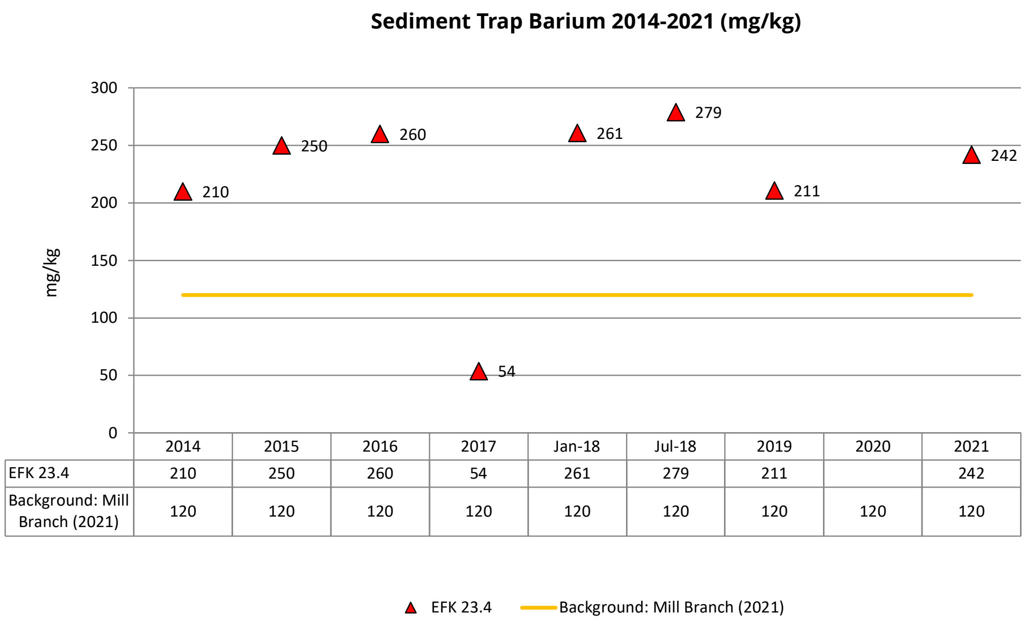
In addition, sample results were compared with data from the background sediment trap sampling station, Mill Branch km 1.6 (MBK 1.6).

The following graphs and associated charts follow the sediment data through recent years. There are some omissions in the charts to be noted:

- The background stream's (Mill Branch) data is shown in the graphs as a bar; this bar symbolizes only the data from 2021.
- Blanks in the following charts (figures 7.1.2-7.1.7), signify the parameter was not analyzed for in that year.
- Analysis of the 10/7/2020 samples was delayed due to budget issues; as a result, the metals samples were held beyond the holding time and the results were not used.

**Barium**

Barium at EFK 23.4 was found to be about twice the concentration of the Mill Branch background station (Figure 7.1.2). There is not a CBSQG for barium. Barium forms insoluble salts with carbonate and sulfate in the environment. As such, it is not mobile and poses little risk. It is found in low levels in most terrestrial soils, but hazardous waste sites may have higher levels. Barium and barium compounds can be found at 798 of the 1,684 current or former NPL sites. Most naturally occurring barium compounds are not a health risk due to their low solubility in water. Other barium compounds that are sometimes found at waste sites include barium acetate, barium chloride, barium hydroxide, barium nitrate, and barium sulfide; these compounds are more soluble in water (ATSDR 2007).




| | 2014 | 2015 | 2016 | 2017 | Jan-18 | Jul-18 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| EFK 23.4 | 210 | 250 | 260 | 54 | 261 | 279 | 211 | | 242 |
| Background: Mill Branch (2021) | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |

**Figure 7.1.2: Sediment Trap Barium: 2014-2021**

### Boron

Boron values were higher than background (Figure 7.1.3). There is not a CBSQG for boron. Boron is the 51st most common element in the earth's crust; the average boron concentration of the entire earth's crust is 8 mg/kg; average soil concentrations are 26-33 mg/kg. Boron combines with oxygen in the environment to form borates. Borate minerals are mined, processed, and used for such purposes as: glass and ceramics, soaps, bleaches, fire retardants, and pesticides (ATSDR 2010). The isotope boron-10 is used as radiation shielding and for radioactivity control. Exposure to humans is primarily through ingestion of food and water or through pesticides or cosmetics containing boron. Adults consume on average about 1.0 to 1.28 mg boron each day (mainly from fruits and vegetables). Boron concentrations in natural soils can be as high as 300 mg/kg; the amounts found in East Fork Poplar Creek, although higher than background, are not out of the ordinary and do not pose a health risk to humans or wildlife.

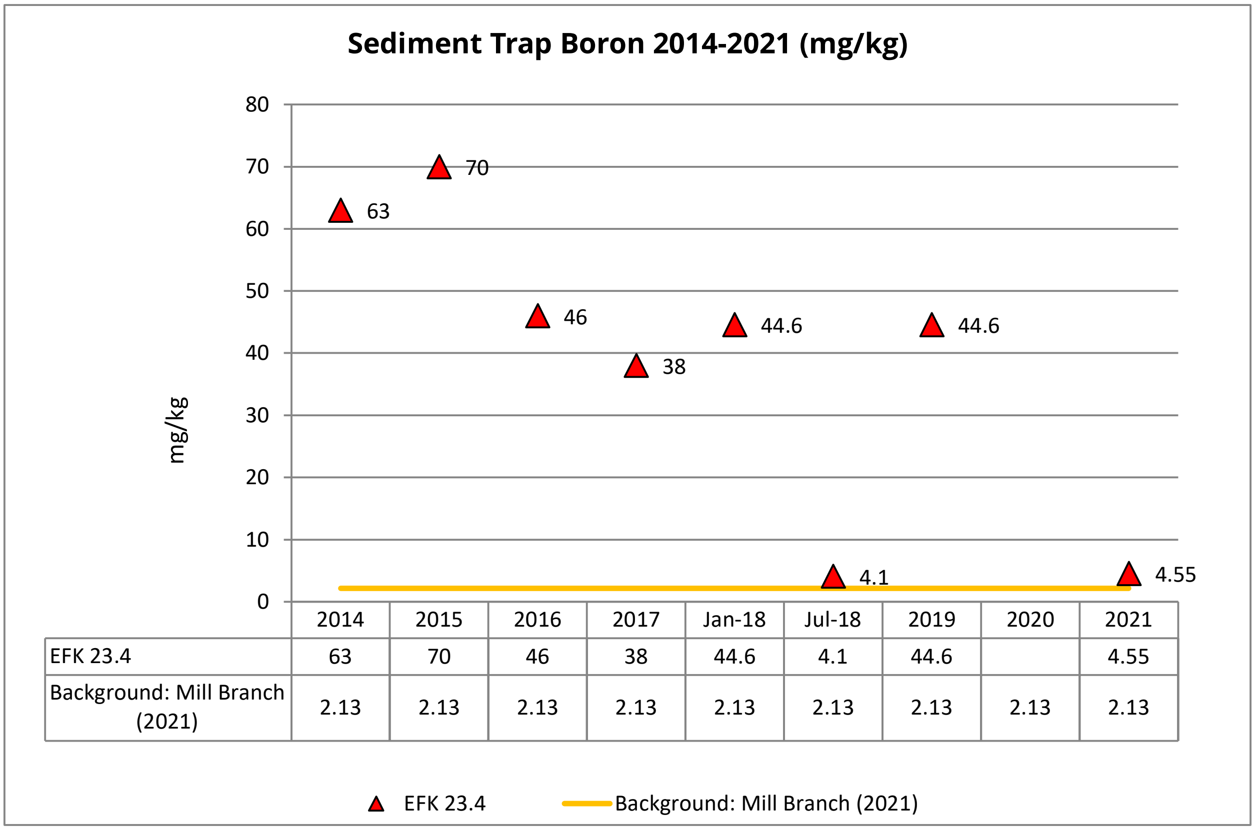
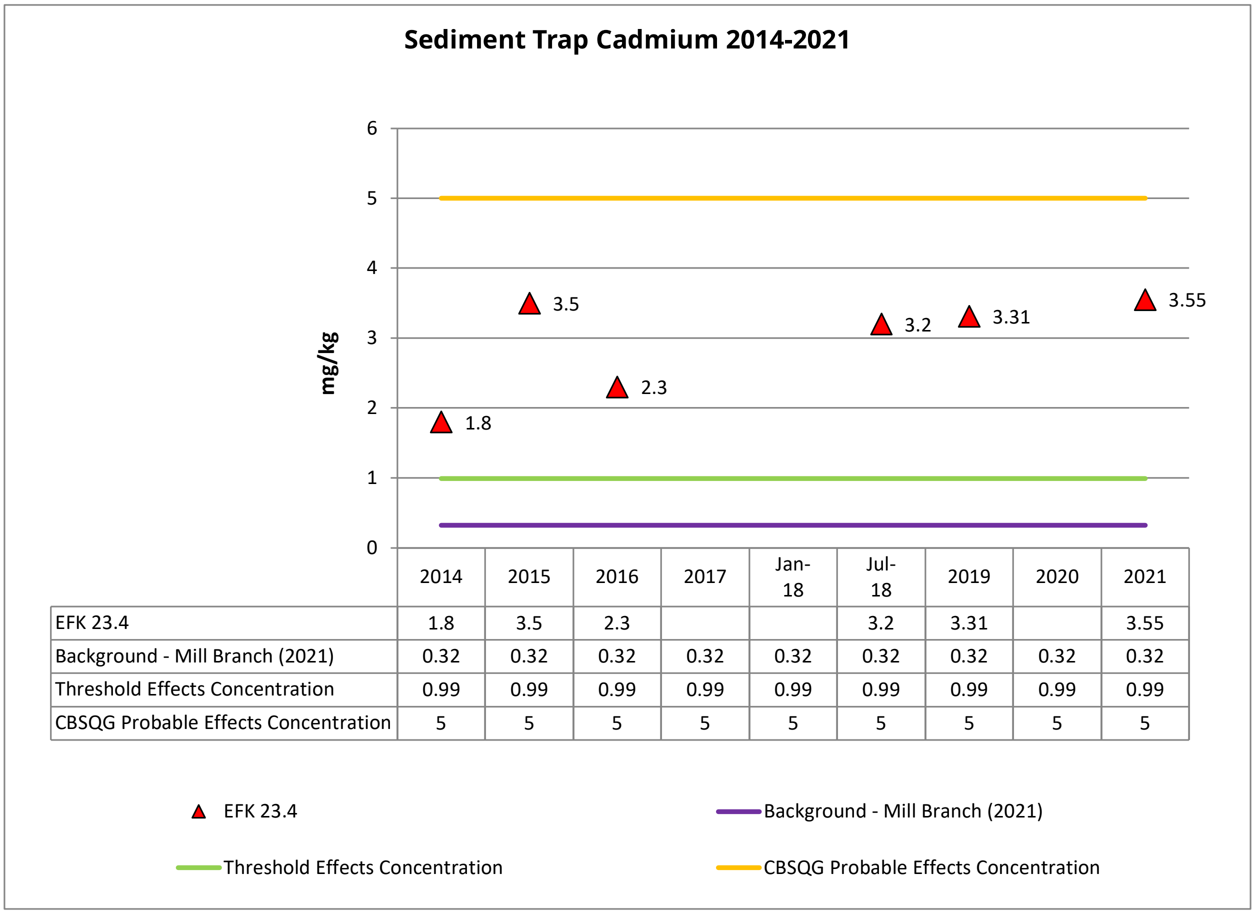



**Figure 7.1.3: Sediment Trap Boron: 2014-2021**

### Cadmium

Cadmium levels at EFK 23.4 were elevated; data were higher than both the TEC and background, but lower than the PEC (Figure 7.1.4). Cadmium is found in the earth's crust, usually associated with zinc, lead, and copper ores and is extracted during the processing of these other metals. Cadmium is predominantly used for batteries (83%), with other uses including pigments, coatings and platings, stabilizers for plastics, nonferrous alloys, and photovoltaic devices. Cadmium chloride and cadmium sulfate are soluble in water. Cadmium binds strongly to organic matter and can bioaccumulate in aquatic organisms and vegetation (ATSDR 2012).

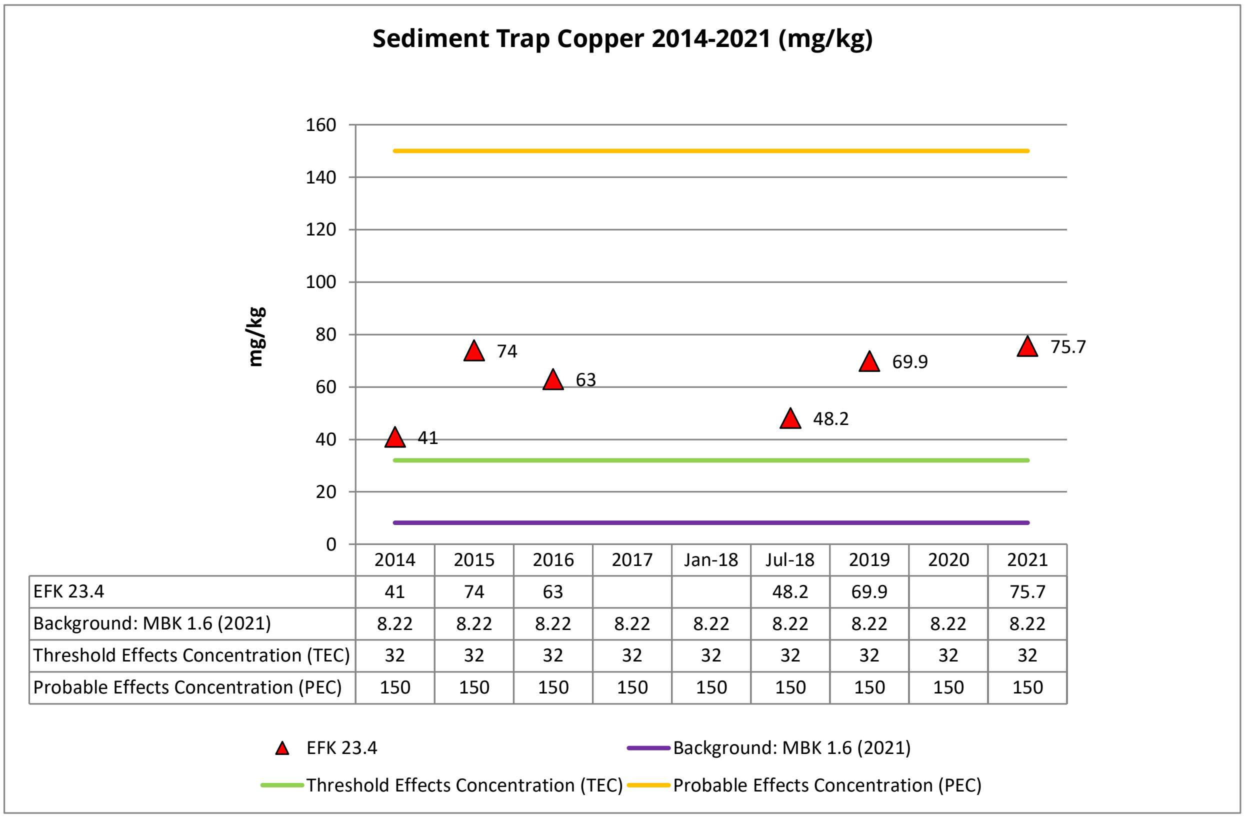



| | 2014 | 2015 | 2016 | 2017 | Jan-18 | Jul-18 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| EFK 23.4 | 1.8 | 3.5 | 2.3 | | | 3.2 | 3.31 | | 3.55 |
| Background - Mill Branch (2021) | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |
| Threshold Effects Concentration | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| CBSQG Probable Effects Concentration | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

**Figure 7.1.4: Sediment Trap Cadmium: 2014-2021**

## Copper

Copper values for EFK 23.4 were consistently higher than the TEC, which could indicate that copper may be contributing a negative impact to benthic macroinvertebrates at this site, particularly when the presence of the other metals that exceed the TEC is considered (Figure 7.1.5). Copper binds strongly to organic matter and minerals and does not travel very far after release in the environment. However, in streams, it can travel far when bound to sediment particles that are capable of being suspended in the current. Copper is stable and does not break down in the environment; it can accumulate in biota where it is found in soils and sediments.

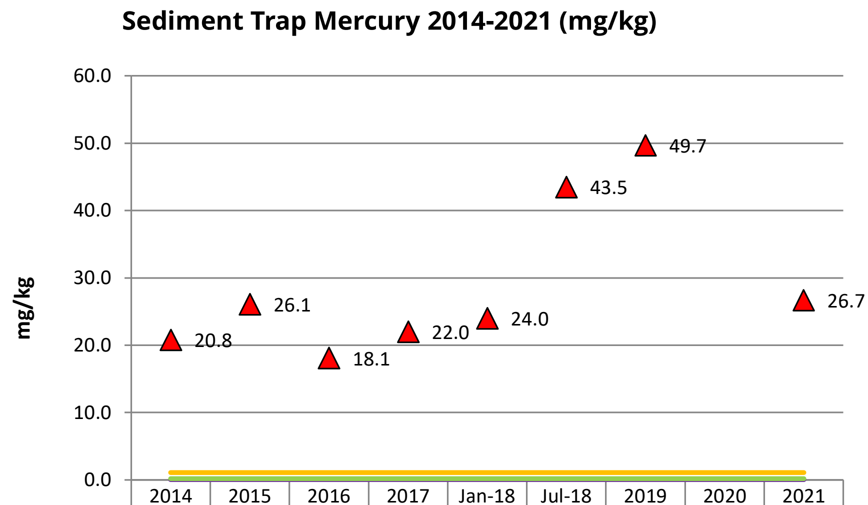



| | 2014 | 2015 | 2016 | 2017 | Jan-18 | Jul-18 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| EFK 23.4 | 41 | 74 | 63 | | | 48.2 | 69.9 | | 75.7 |
| Background: MBK 1.6 (2021) | 8.22 | 8.22 | 8.22 | 8.22 | 8.22 | 8.22 | 8.22 | 8.22 | 8.22 |
| Threshold Effects Concentration (TEC) | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| Probable Effects Concentration (PEC) | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |

**Figure 7.1.5: Sediment Trap Copper: 2014-2021**

### Mercury

Mercury values for EFK 23.4 were much higher than the PEC (Figure 7.1.6); metals found at levels above the PECs indicate that the metal(s) in question were probably having an adverse effect on benthic macroinvertebrate populations. Mercury occurs naturally in the environment as metallic mercury (elemental mercury), inorganic mercury (mercuric sulfide and mercuric chloride), and organic mercury (methylmercury). Large quantities (11 million kilograms) of elemental mercury were used at the Y-12 plant from 1950 to 1963 for a lithium isotope separation process. Loss of mercury to the air, soil and to EFPC are estimated to be 3% of the mercury used at the site. Mercury continues to be released to the creek from contaminated soil and groundwater sources at Y-12 (Brooks and Southworth 2011). Anthropogenic releases of mercury are predominantly emissions to the air from fossil fuel combustion, mining, and smelting. Solid waste incinerators also contribute releases of mercury. A smaller fraction of the anthropogenic contribution is agricultural mercury-containing fungicides used up until the 1970's and municipal solid waste containing old batteries, electrical switches, and thermometers. Methylmercury is a major health concern because it accumulates in fish and aquatic mammals to a great extent. If elemental mercury is present, bacteria and fungi produce most of the methylmercury in the environment by the process of methylation (ATSDR 1999).




| | 2014 | 2015 | 2016 | 2017 | Jan-18 | Jul-18 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| EFK 23.4 | 20.8 | 26.1 | 18.1 | 22.0 | 24.0 | 43.5 | 49.7 | | 26.7 |
| Background: MBK 1.6 (2021) | 0.0539 | 0.0539 | 0.0539 | 0.0539 | 0.0539 | 0.0539 | 0.0539 | 0.0539 | 0.0539 |
| Threshold Effects Concentration (TEC) | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| Probable Effects Concentration (PEC) | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |

EFK 23.4 — Background: MBK 1.6 (2021) — Threshold Effects Concentration (TEC) — Probable Effects Concentration (PEC)

**Figure 7.1.6: Sediment Trap Mercury: 2014-2021**

## Uranium

Uranium values were greater than background at EFK 23.4 from 2014-2021 (Figure 7.1.7). Over the years, there may be a significant upward trend ($p<0.05$; R^2=0.55) of uranium concentration in the suspended sediment found at EFK 23.4. Calculations estimate that there is approximately a 0.97 mg/kg increase per year. There are no CBSQGs established for uranium. Uranium is a dense, silver-white, radioactive metal in its pure state. It is found in the environment in rocks, soil, water, and air in very small amounts. Phosphate fertilizers usually contain considerable amounts of uranium due to the materials from which they are made. Mining and erosion from mine tailings can result in increased amounts of uranium in the environment. Uranium became more prevalent in the environment with the development of nuclear energy applications, such as nuclear power plants and weaponry. A large quantity of uranium was used at the Oak Ridge Gaseous Diffusion Plant (former K-25 site) and much of the uranium waste was buried in landfills in the Bear Creek Valley. Uranium has also been used at the Oak Ridge Y-12 plant. Exposure to small amounts of natural uranium is not particularly dangerous. People who are exposed to high amounts of uranium, particularly enriched uranium, have a chance of developing cancer. Nuclear power plant accidents can result in the release of enriched uranium to the environment.

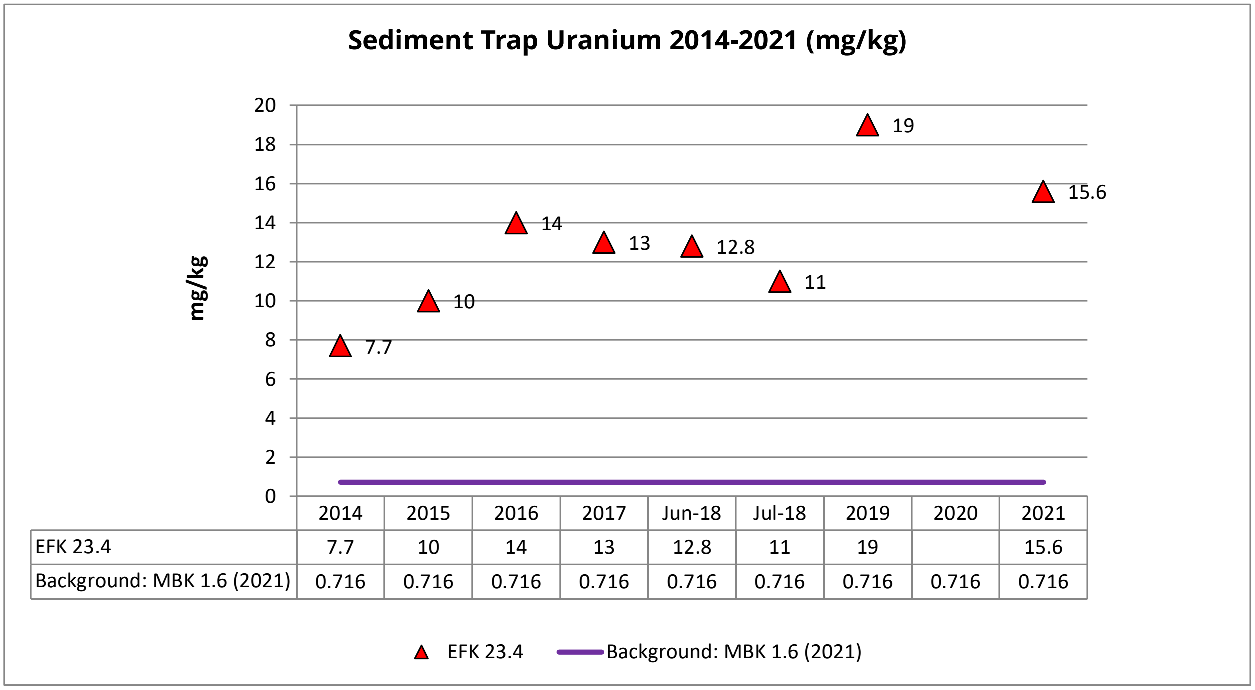



**Figure 7.1.7: Sediment Trap Uranium: 2014-2021**

### Arsenic, Chromium, Lead, and Nickel

Arsenic in sediments at EFK 23.4 (5.02 mg/kg) was lower than the TEC (9.8 mg/kg). Chromium values are below the TEC. Lead values for EFK 23.4 are positioned around the TEC, some slightly higher and some slightly below. Nickel is greater than background (10.4 mg/kg) at EFK 23.4 (23.8 mg/kg) in all years, except for the 2017 datum. The nickel data are clustered around the TEC (23 mg/kg).

When there are several metals with concentrations above the CBSQGs, the metals have a negative synergistic effect on biota.

### Gross Alpha

Gross alpha activity was greater than background in the sediment trap samples in most years but was less than background (n=3) in 2021 (Figure 7.1.8). It is unusual that the value for uranium concentration was the highest recorded since 2014, but the gross alpha was the lowest. It may be that the uranium present is predominantly U-238, which has the lowest rate of alpha emission of the common uranium isotopes. The background MBK 1.6 value of 3.03 pCi/g is the mean of the years 2018, 2019, and 2021.

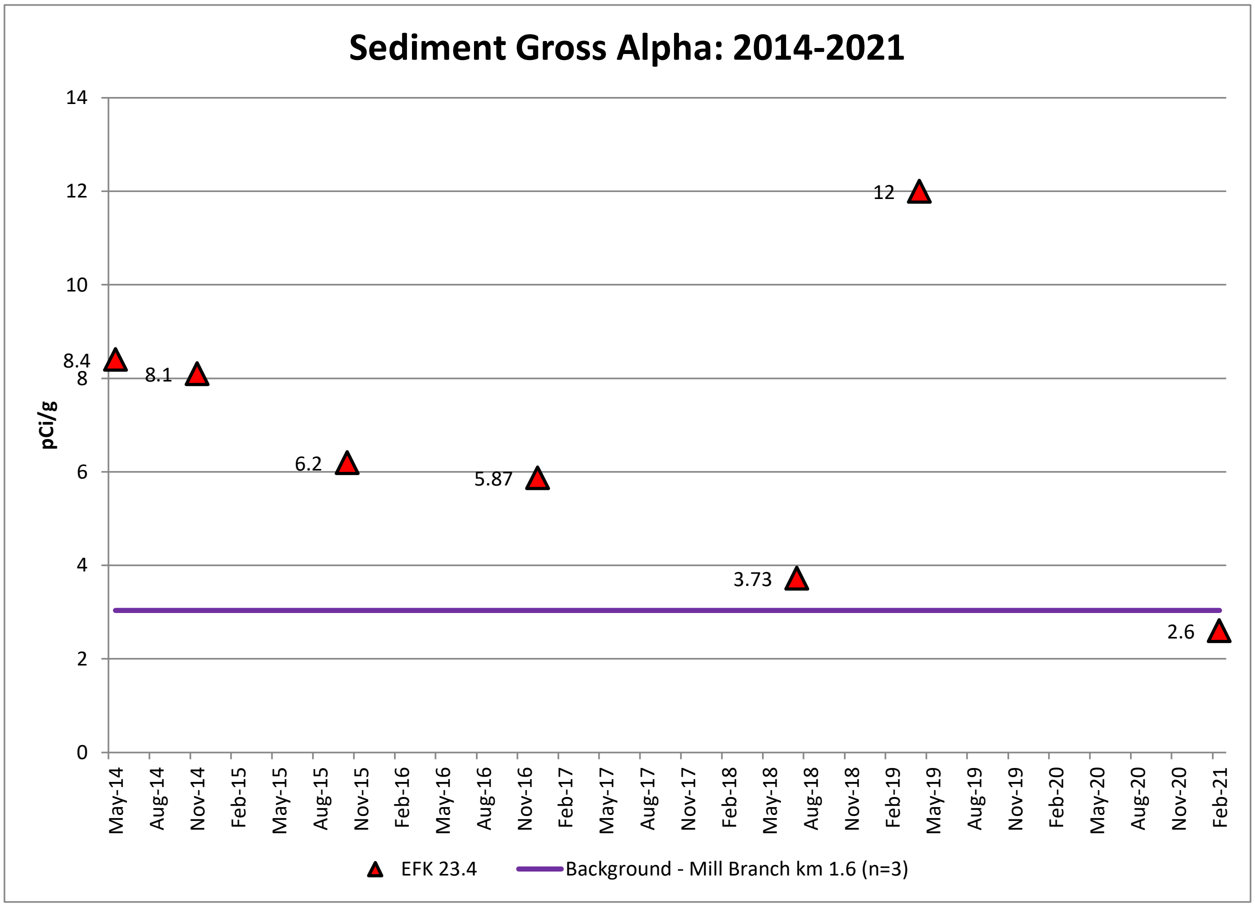



**Figure 7.1.8: Sediment Trap Gross Alpha**

### Gross Beta

Gross beta activity was greater than background in the sediment trap samples (Figure 7.1.9). Both the U-238 and U-235 decay series produce several beta-emitting daughter nuclides with very short half-lives, (e.g., bismuth-214 and lead-214) and may be causing the elevated beta radioactivity in suspended sediment at EFK 23.4. The background MBK 1.6 value of 4.53 pCi/g is the mean of the years 2018, 2019, and 2021.

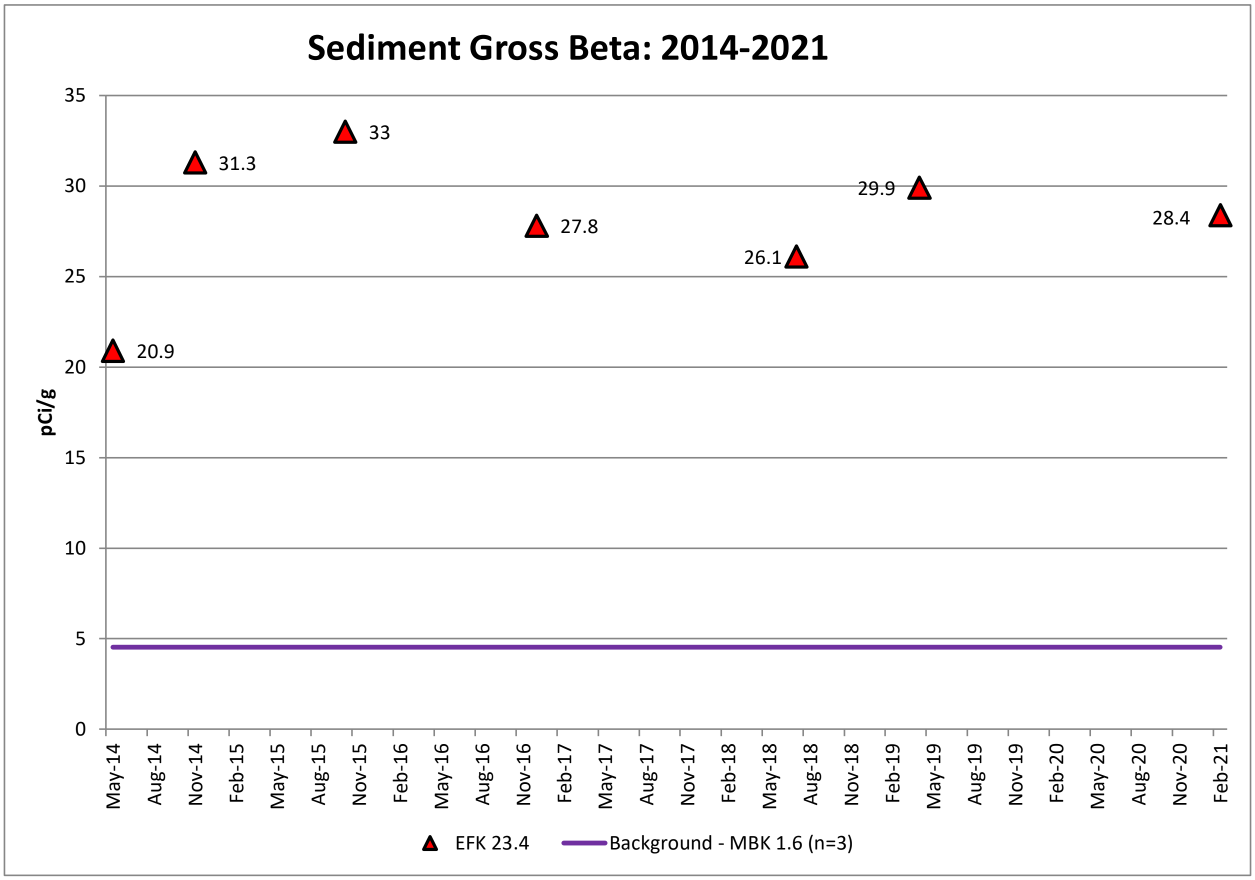



**Figure 7.1.9: Sediment Trap Gross Beta**

### Uranium Isotopes

The uranium metal concentrations were much higher in the EFK 23.4 sediment than the MBK 1.6 background site. A closer look at the individual uranium isotopes present in that sample, reveals that the uranium isotope in greatest concentration based on radiological activity is U-238 (6.27 pCi/g) (Figure 7.1.10).

Comparing the pCi per gram of sediment material for each isotope shows that U-238's activity has the highest contribution at 6.1 times the level of the of the background site. U-234 and U-235 in the sediment sample (pCi/g sediment) have activities of 4.2- and 2.3-times background, respectively.

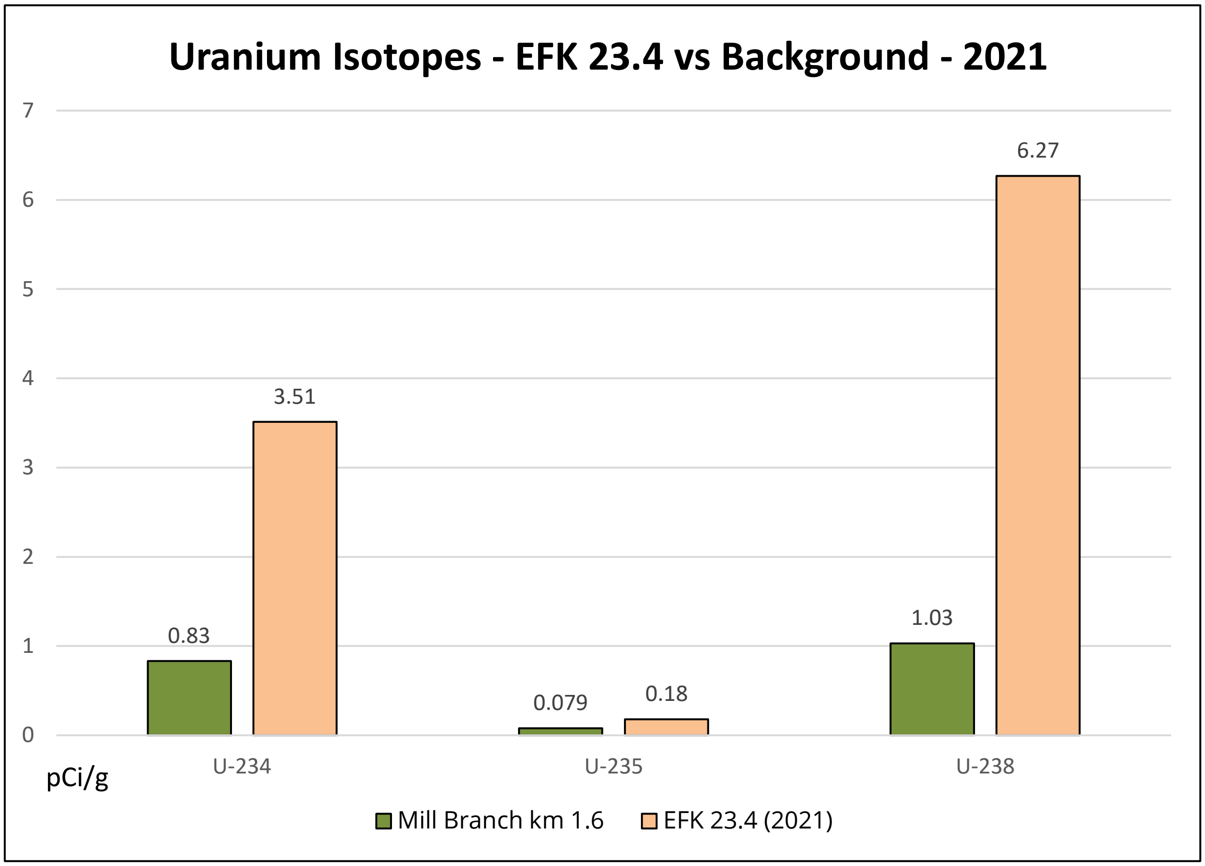



**Figure 7.1.10: Sediment Uranium Isotopes**

**Gamma Radionuclides**

Some naturally occurring gamma-emitting radionuclides were detected. These radioisotopes, such as bismuth-214, potassium-40, lead-212 and others had similar levels of gamma radioactivity as did the background station, MBK 1.6.

## 7.1.8 Conclusions

The analysis of sediment collected from the sediment traps indicate that for FY21 (this period of performance) metals contamination at EFK 23.4 where cadmium and copper levels were above the TEC and mercury levels, exceeded the PEC.

Lead and nickel concentrations were above the TEC in 2015, 2016, and in this sampling event for FY2021 as well.

When a metal occurs at a concentration above the TEC, a possibility of impairment to benthic macroinvertebrate populations exists. Above the PEC, it is probable that these populations will be impaired. The concentrations of these metals indicate that there is a probable impairment to the biota at EFK 23.4.

EFK 23.4 also has levels of gross alpha and beta radioactivity that are above background in the trapped sediment samples collected. Uranium isotope data show all three uranium isotopes (U-234, U-234, and U-238) have greater radioactivity than the background site. This corelates to the uranium metals data collected from that same sample. Gamma radioactivity is not a concern; and while some naturally occurring gamma radionuclides were detected and their activity was similar to the background site.

### 7.1.9 Recommendations

These sediment traps capture suspended sediments that are being carried by the stream. Analysis of the sediments collected in this manner gives an idea of what has been travelling down the stream in the period that the trap was deployed. Sediment traps provide an intermediary form of information between sediment grab sampling and surface water sampling. It is the purpose of this project to stay abreast of the quality of sediment being transported in the ORR exit pathway streams. The DoR-OR trapped sediment project is needed to provide this information. In the coming years, it is anticipated there will be many decommissioning and demolition (D&D) projects as well as construction projects in the upper East Fork Poplar Creek watershed. To provide ample information about East Fork Poplar Creek in the years ahead, the trapped sediment project should be continued and funded as necessary.

### 7.1.10 References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ATSDR. 2012. *Toxicological Profile for Cadmium*. September 2012. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. Available from: https://www.atsdr.cdc.gov/ToxProfiles/tp5.pdf . [Accessed 23 June 2021].

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MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology. 39:20-31. 2000.

Phillips, J. M., Russell, M.A., and Walling, D.E. (2000). Time-integrated sampling of fluvial suspended sediment: a simple methodology for small catchments: Hydrological Processes, v. 14, no. 14, p. 2,589-2,602.

United States Environmental Protection Agency. Field Branches Quality System and Technical Procedures: Field Sampling Procedures – Sediment Sampling Region IV, Athens, GA. 2010

WDNR 2003. *Consensus-based Sediment Quality Guidelines: Recommendations for Use & Application, Interim Guidance.* PUBL-WT-732 2003. Wisconsin Department of Natural Resources.

# 8.0 STORM WATER / WATER DISCHARGE MONITORING

## 8.1 RAIN EVENT

### 8.1.1 Background

Rainwater is not static; it moves through soil, enters buildings, gathers in sumps, and low spots of drainage systems. During this movement, rainwater can accumulate contaminants that need to be treated before it is discharged to the environment. DOE collects storm water samples for compliance with the National Pollutant Discharge Elimination System (NPDES) at selected discharge points across the Oak Ridge Reservation. With DOE D&D activities and Remedial Actions expanding throughout the Oak Ridge Reservation, TDEC DoR-OR uses this program to provide oversight of sampling events related to CERCLA related discharges and to create baseline monitoring before remedial actions begin.

### 8.1.2 Problem Statements

- Rainwater moving through abandoned buildings, across disturbed ground and entering storm sewers may become contaminated with contaminants specific to the building and the area.
- Rainwater that has become contaminated as it passes through D&D areas can be discharged into the environment.

### 8.1.3 Goals

The goal of this project is to obtain data to evaluate DOE's remedial actions and to provide

input for future cleanup decisions. Actions to achieve this goal follow:

- Monitor ORR storm drains (SD) that are or may be affected by remediation activities to gather data for the evaluation of D&D and Remedial actions.
- Use sampling to monitor releases into the environment.
- Observe DOE sampling activities associated with D&D and RA activities.
- Review DOE sampling results.

### 8.1.4 Scope

The scope of this project was to assess, monitor, observe, sample outfalls, and analyze data pertaining to rain events associated with DOE's ORR remedial actions.

### 8.1.5 Methods, Materials, Metrics

TDEC DoR-OR sampling for storm events followed basic guidelines from the EPA NPDES Storm Water Sampling Guidance Document (EPA 833-8-90-001 July 1992). The stormwater guidance trigger for monitoring is for a 1” rainfall event in a 24-hour period, preceded by at least 72 hours of dry weather. To create a baseline, TDEC DoR-OR attempted to take samples during dry periods if outfall flow was sufficient. After a period of 36 hours where the total precipitation was less than 0.1 inches, dry flow sampling was attempted.

In May 2021, TDEC DoR-OR requested that DOE provide sampling results to TDEC DoR-OR for each rain event sampling conducted to monitor CERCLA actions at Y-12.

### 8.1.6 Deviations from the Plan

TDEC DoR-OR attempted to collect samples from outfalls during times that met the definition of a dry weather discharge. TDEC DoR-OR found no discharges during dry weather conditions.

### 8.1.7 Results and Analysis

On September 14, 2020, TDEC DoR-OR observed and collected a sample from Manhole 100 at ETTP. This was the final sampling event for CERCLA actions at ETTP. Results are presented in Table 8.1.1.

TDEC DoR-OR collected quarterly samples from three outfalls (055, 063, 064) at Y-12 beginning in October 2020. Collected samples were analyzed for:

- Metals: uranium, beryllium, mercury, and low-level mercury
- Radiological: gross alpha/beta, uranium-234, uranium-235, uranium-238

The October 2020 to May 2021 results are presented in Table 8.1.2 and 8.1.3.

**Table 8.1.1 (September 2020 Metals Results)**

| Outfall | Date | Arsenic | Chromium | Lead | Manganese | Mercury | Units |
|---|---|---|---|---|---|---|---|
| 100 | 9/14/2020 | <1.35 | <3.11 | <0.144 | 93.3 | <0.0405 | µg/L |

**Table 8.1.2 (October 2020 – May 2021 Metals Results)**

| Outfall | Date | Uranium | Mercury | Beryllium | Low-Level Mercury | Units |
|---|---|---|---|---|---|---|
| 055 | 10/29/2020 | 0.363 | 0.0668 | <0.243 | * | µg/L |
| 063 | 10/29/2020 | 0.734 | <0.0405 | <0.243 | 0.0368 | µg/L |
| 064 | 10/29/2020 | 0.735 | <0.0405 | <0.243 | 0.00467 | µg/L |
| 055 | 1/26/2021 | 1.14 | 0.0534 | <0.243 | * | µg/L |
| 063 | 1/26/2021 | 3.75 | 1.4 | <0.243 | * | µg/L |
| 064 | 1/26/2021 | 1.4 | 0.0539 | <0.243 | * | µg/L |
| 055 | 5/4/2021 | 0.68 | 0.0415 | <0.243 | * | µg/L |
| 063 | 5/4/2021 | 0.402 | 0.0664 | <0.243 | * | µg/L |
| 064 | 5/4/2021 | 1.74 | * | <0.243 | 0.0288 | µg/L |

* Contaminant was not analyzed for.

**Table 8.1.3 (October 2020 – May 2021 Radiological Results)**

| Outfall | Date | Gross Alpha | Gross Beta | Uranium-234 | Uranium-235 | Uranium-238 | Units |
|---|---|---|---|---|---|---|---|
| 055 | 10/29/2020 | 0.58 | 1.6 | 0.319 | 0.054 | 0.139 | pCi/L |
| 063 | 10/29/2020 | 0.9 | 0.4 | 0.469 | 0.042 | 0.262 | pCi/L |
| 064 | 10/29/2020 | 0.51 | 1.2 | 0.46 | 0.053 | 0.214 | pCi/L |
| 055 | 1/26/2021 | 1.51 | -0.6 | 1 | 0.83 | 0.448 | pCi/L |
| 063 | 1/26/2021 | 2.72 | 0.59 | 1.97 | 0.176 | 0.91 | pCi/L |
| 064 | 1/26/2021 | 1.43 | -0.3 | 1 | 0.104 | 0.53 | pCi/L |
| 055 | 5/4/2021 | 0.06 | 5 | 0.279 | 0.043 | 0.115 | pCi/L |
| 063 | 5/4/2021 | 0.63 | 4.8 | 0.503 | 0.056 | 0.216 | pCi/L |
| 064 | 5/4/2021 | 2.09 | 2.4 | 0.95 | 0.166 | 0.7 | pCi/L |

### 8.1.8 Conclusions

The independent Rain Event Surface Water Project performed by DoR-OR provides an oversight of the DOE monitoring program associated with the CERCLA activities on the ORR. DOE results are adequately reviewed for compliance. DOE field operations are assessed against Standard Operating Procedures (SOP) for any variations. DoR-OR sampling provides a check against DOE reported values.

### 8.1.9 Recommendations

As remedial activities continue and move to new locations on the ORR, there is the potential for a negative impact on the environment from rain events. DoR-OR recommends continued oversight of DOE CERCLA activities at Y-12 and ORNL where contaminants and contaminant mobility issues may be encountered.

### 8.1.10 References

UCOR Surface Water Sampling – Manual and Automated (2018) SOW-MS-PROCES2203-1278

Rules of the Tennessee Department of Environment and Conservation. General Water Quality Criteria 0400-40-03

## 8.2 ACCUMULATED WATER DISCHARGES

### 8.2.1 Background

Rainwater and groundwater are not static. They accumulate, pool, and seep into basements, basins, and soil (from excavations, D&D activities, and remedial actions (RA)). Most of this water accumulation contains at least one contaminant that needs to be treated before it is discharged to the environment. Beginning in 2018 DOE created and operated treatment systems for the remediation of accumulated water. DoR-OR, in cooperation with DOE and its contractors, conducted random oversight of sampling activities at the treatment systems. In addition to performing the sampling oversights, DoR-OR reviews the analytical results provided by DOE and does periodic sampling at the treatment systems. The overall goal of the program is to monitor DOE efforts in preventing contamination from leaving the reservation (ORR).

### 8.2.2 Problem Statements

- Contamination from legacy and ongoing activities can be disturbed and transported beyond the physical boundaries of the ORR by D&D or RA activities during a rain event.

- Water can accumulate in D&D or RA areas through entry into basins, sumps, basements, or during soil remediation activities. Accumulated water may become contaminated and dispersed into the environment.

### 8.2.3 Goals

The goal of this project is to obtain data to evaluate DOE's remedial actions and to provide input into the future of cleanup decisions. Actions to achieve this goal include:

- Use split and or independent sampling to monitor releases into the environment.

- Observe sampling activities associated with accumulated water treatment systems aligned with CERCLA activities.

- Review DOE sampling results.

### 8.2.4 Scope

The scope of this project was to assess, monitor, observe and analyze data pertaining to accumulated water treatment systems associated with DOE's remedial actions.

### 8.2.5 Methods, Materials, Metrics

Sampling events were scheduled when a treatment system had accumulated enough treated water for release. DOE contractors notified DoR-OR staff when sampling events were scheduled. If available, DoR-OR staff members completed biased oversight of the sampling events using the Edgewater Technical Associates "Outfall 200 Mercury Treatment Facility Liquid Waste Sampling" and ARS Aleut Remediation (ARS) "Sampling and Analysis Plan for Water/Solid Waste Management During Construction of the Outfall 200 Mercury Treatment Facility at the Y-12 National Security Complex Oak Ridge, Tennessee" guidance documents as reference.

Upon notification of a sampling event, staff members gathered necessary Personal Protective Equipment (PPE) and proceeded to the sampling area. Each sampling event was observed as close to the sampling point as possible, while avoiding any interference with the sampling process.

For treatment systems with tanks as water containers, observation was made from the catwalk if possible. Following the guidelines of the "Outfall 200 Mercury Treatment Facility Liquid Waste Sampling" document observers noted the order that samples were taken, the sampling procedures, the sampling tools and equipment used, and disposal of excess liquids.

If two DoR-OR staff members were present for the oversight, one staff member observed the sampling, while the other staff member observed the transport, labeling, bagging, and storage of the samples. If any action was observed to be in violation of the reference document, it was noted in the field book and a discussion was held with the field samplers before further action was taken.

### 8.2.6 Deviations from the Plan

There were no deviations from the plan.

### 8.2.7 Results and Analysis

Oversight of the sampling operations at the Outfall 200 Mercury Treatment Facility was begun in February 2020. RSI was the contractor taking the samples at that time. RSI provided the SOP (Standard Operating Procedures) that was in use for sampling events, in March 2020. TDEC DoR-OR made observations based on that document until Edgewater Technical Associates took over the sampling in late March and provided its SOP. Approximately 15% of sampling events were observed from July 1, 2020 to June 31, 2021 at the treatment system.

DOE sampled the treatment system water tanks on 11/2/2020 and 2/12/2021. To ensure the quality of DOE's results, TDEC DoR-OR collected duplicate samples from one of the tanks concurrently. On 3/3/2021 and 4/4/2021 DOE collected samples from two treated water tanks. DOE duplicated these samples, utilizing two different contractors to ensure the quality of their data (Table 8.2.1).

In July 2021, DOE provided the results to DoR-OR from all sampling events conducted at the treatment site. The results covered the time from September 2019 to June 2021 (Table 8.2.1). Averages were calculated from each quarter, for both treated and untreated samples, and shown in Figure 8.2.1.

**Table 8.2.1**

| Date | Analysis | Result ng/L | Sampler |
|---|---|---|---|
| 11/2/2020 | Hg | 65.1 | DoR-OR |
| 11/2/2020 | Hg | 53.0 | DOE |
| 2/10/2021 | Hg | 81.2 | DoR-OR |
| 2/10/2021 | Hg | 140.0 | DOE |
| 3/18/202 | Hg | 32.9 | Contractor 1 |
| 3/18/2021 | Hg | 55.8 | Contractor 2 |
| 3/18/2021 | Hg | 79.1 | Contractor 1 |
| 3/18/2021 | Hg | 94.4 | Contractor 2 |
| 4/08/2021 | Hg | 526 | Contractor 1 |
| 4/08/2021 | Hg | 880 | Contractor 2 |
| 4/08/2021 | Hg | 742 | Contractor 1 |
| 4/08/2021 | Hg | 781 | Contractor 2 |

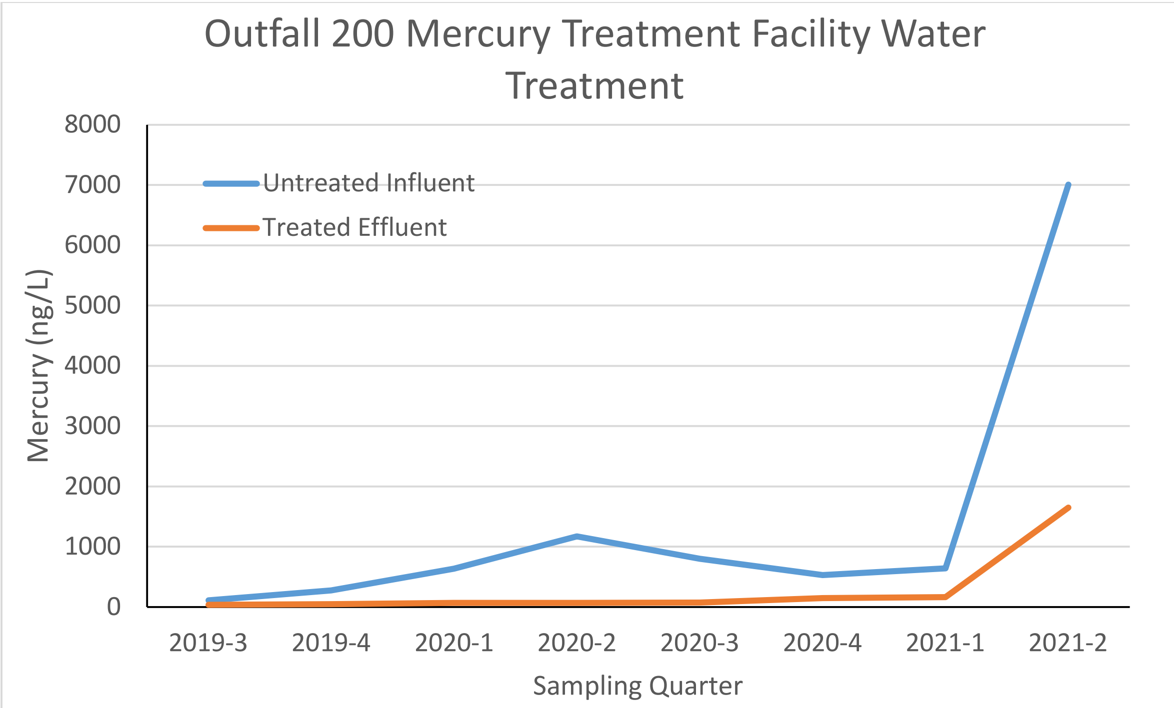


**Figure 8.2.1 (Quarterly Influent and Effluent Mercury Average Results)**

### 8.2.8 Conclusions

The oversight of sampling activities associated with Mercury Treatment Facility shows that the samples were collected following the guidelines of the Standard Operating Procedures that were presented to DoR-OR. Analysis of the sampling results provided to DoR-OR showed that the level of mercury has increased over the course of the system's operation, especially in 2021. This increase aligns with attempts to lower the groundwater level around the construction area, by installing groundwater wells and pumping groundwater to the Outfall 200 Mercury Treatment Facility.

### 8.2.9 Recommendations

As remedial activities spread across the ORR, the need for water treatment systems may increase. DoR-OR recommends continued oversight of treatment systems and monitoring of trends in effluent concentrations on the ORR.

### 8.2.10 References

UCOR Surface Water Sampling – Manual and Automated (2018) SOW-MS-PROCES2203-1278

Rules of the Tennessee Department of Environment and Conservation. General Water

Quality Criteria 0400-40-03

ARS Aleut Remediation, LLC (AAR) – Sampling and Analysis Plan for Water/Solid Waste Management During Construction of the Outfall 200 Mercury Treatment Facility at the Y-12 National Facility at the Y-12 National Security Complex Oak Ridge, Tennessee

Edgewater Technical Associates – Outfall 200 Mercury Treatment Facility Liquid Waste Sampling

# 9.0 SURFACE WATER MONITORING

## 9.1 AMBIENT SURFACE WATER PARAMETERS

### 9.1.1 Background

The ORR consists of three (3) major sites: ORNL, Y-12, and ETTP. Activities at these sites, both historically and now, have resulted in the discharge of hazardous substances (e.g. metals, organics, and radioactive materials) leading to the contamination of waterbodies on the ORR and in the surrounding areas (DOE, 1992; DOE, 2018; Pickering, 1970; Turner & Southworth, 1999). While legacy waste across the ORR may be responsible for a large portion of the contamination to surface water, current projects and processes at these sites also have the potential to significantly contribute to surface water contamination.

In an effort to both complement and verify the DOE environmental program and to ensure the citizens and environmental resources of Tennessee are not severely impacted by surface water contamination, this Ambient Surface Water Parameter Project has been implemented each year since 2005. This Project aims to assess the degree of surface water impact relative to potential contamination displacement. To accomplish this, stream monitoring data are collected monthly to establish and build upon a database of physical stream parameters (conductivity, pH, temperature, and dissolved oxygen).

### 9.1.2 Problem Statements

ORR exit-pathway streams and the Clinch River have been and are currently subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These releases can be detrimental to the environment and to human health.

Identified concerns include but are not limited to the following:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury into East Fork Poplar Creek (EFPC). Mercury has been released into the environment by spills, leakage from subsurface drains, and purposed discharge of wastewater. Contaminated building foundations and soils also contributed to these mercury releases (Turner and Southworth, 1999).

- EFPC is believed to contribute approximately 0.2 metric tons of mercury into the Clinch River each year (DOE, 1992).

- Besides mercury, other metals that have been found in ORR exit pathway streams at levels greater than background include cadmium, chromium, lead, nickel, silver and zirconium (DOE, 1992).

### 9.1.3 Goals

- Create a database/baseline of surface water conditions on and around the ORR.
- Assess site remediation efforts through long-term monitoring of surface water.
- Record ambient conditions that can be used for comparisons in the event of accidents that may have impacted surface water bodies.

### 9.1.4 Scope

Due to the presence in some areas of anthropogenic point- and non-point source contamination on the ORR and the potential for contamination to impact surface water parameters, this project was limited to collecting and recording physical stream parameter measurements of ambient surface water of the exit pathway streams that drain the ORR to establish a baseline of conditions on and around the ORR.

### 9.1.5 Methods, Materials, Metrics

The surface water physical parameters of temperature, pH, conductivity, and dissolved oxygen were measured monthly with an YSI Professional Plus multi-parameter water quality instrument. Field monitoring followed the 2018 Tennessee Department of Environment and Conservation (TDEC), Division of Water Resources (DWR), *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2018).

**Table 9.1.1: Monitoring Locations**

| Site DWR Name | DOE-O Site Description | DOE-O Site | Site Latitude | Site Longitude |
|---|---|---|---|---|
| EFPOP014.5AN | East Fork Poplar Creek Mile 14.5 | EFK 23.4 | 35.99596 | -84.24004 |
| EFPOP008.6AN | East Fork Poplar Creek Mile 8.6 | EFK 13.8 | 35.99283 | -84.31371 |
| BEAR007.6AN | Bear Creek Mile 7.6 | BCK 12.3 | 35.973 | -84.27814 |
| BEAR006.0AN | Bear Creek Mile 6.0 | BCK 9.6 | 35.96032 | -84.29741 |
| BEAR002.8RO | Bear Creek Mile 2.8 | BCK 4.5 | 35.9375 | -84.33938 |
| MITCH000.1RO | Mitchell Branch Mile 0.1 | MIK 0.1 | 35.94146 | -84.3922 |
| FECO67I12 | Mill Branch Mile 1.0 | MBK 1.6 | 35.98886 | -84.28935 |

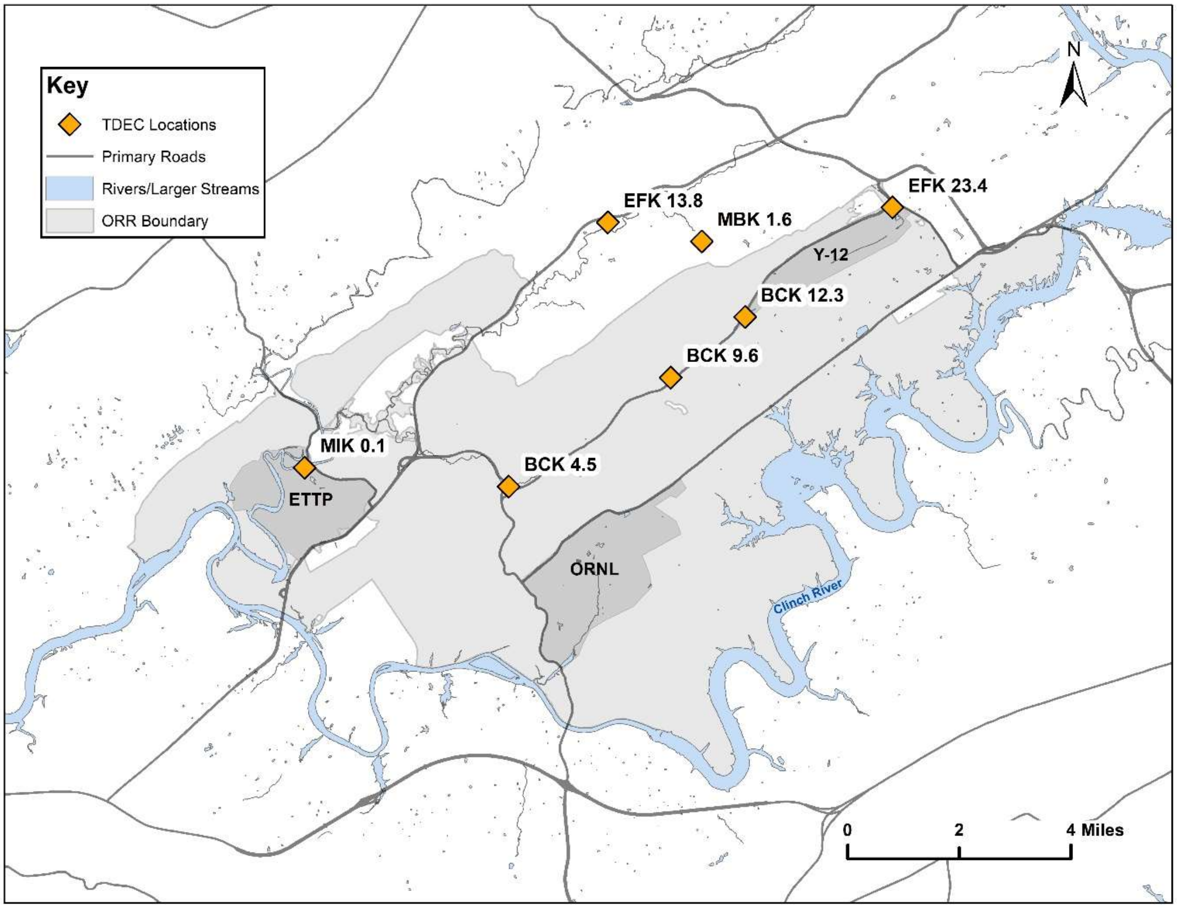


**Figure 9.1.1: Map of surface water parameter locations.**

## 9.1.6 Deviations from the Plan

No deviations from the plan occurred for this project.

## 9.1.7 Results and Analysis

Field parameters including conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven monitoring locations (Figure 9.1.1 and Table 9.1.1). These data generally seemed to follow similar patterns over time for each respective parameter. However, a few monitoring locations had slight deviations for certain parameters. Significant differences among streams were analyzed and are discussed below (Figure 9.1.2).

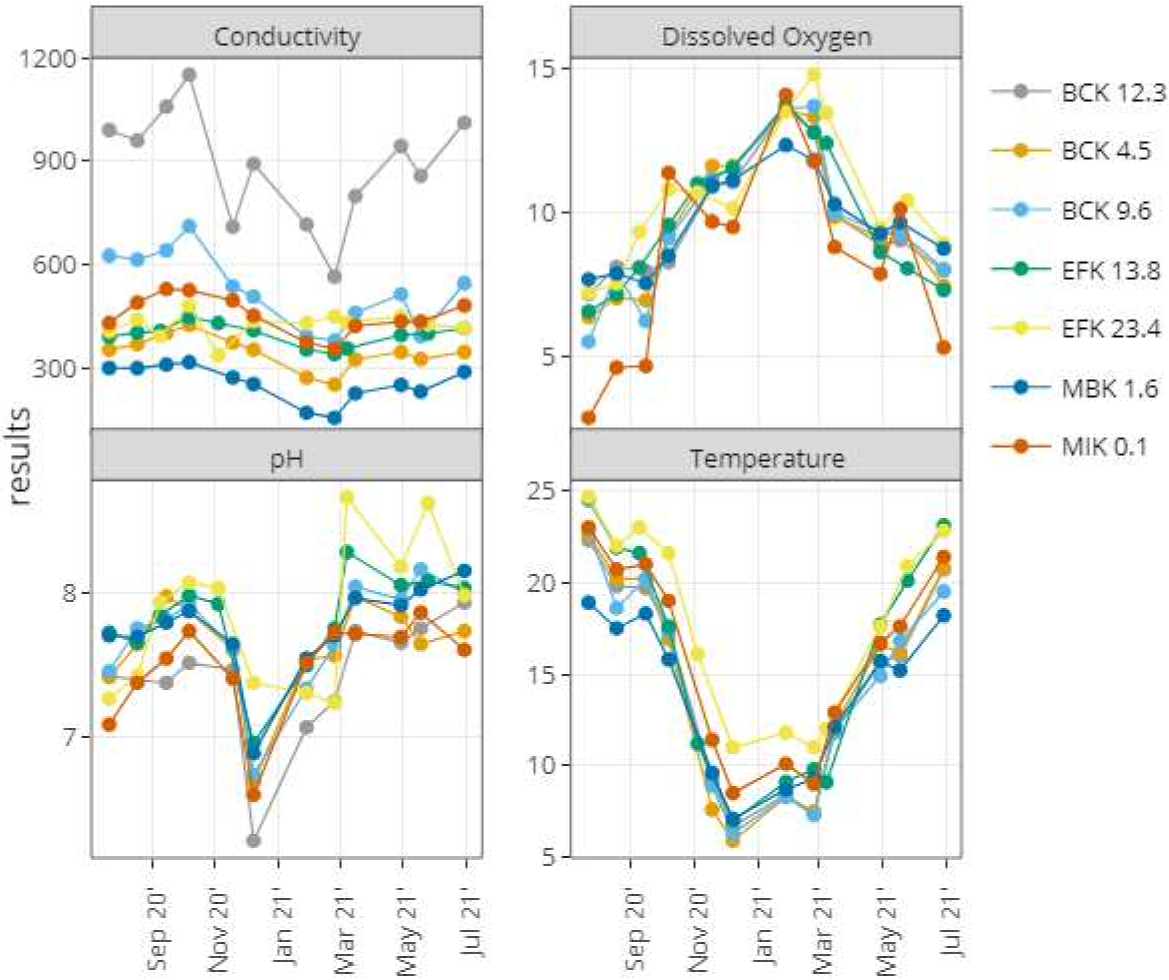


**Figure 9.1.2: Field parameter results from July 2020 through June 2021. Units for conductivity, dissolved oxygen, pH, and temperature are µS/cm, mg/L, std. unit, and ºC, respectively.**

One of the field parameters with significant differences among streams was conductivity. Mean conductivity values from measurements collected July 2020 to June 2021 ranged from 887 to 255 µS/cm, among all of the monitoring sites. Bear Creek sites BCK 12.3 and BCK 9.6 had the highest mean conductivity values of 887 and 526 µS/cm, respectively. Further downstream, BCK 4.5 had a lower mean value of 344 µS/cm. At EFPC, site EFK 23.4, near the eastern border of the Y-12 Security Complex, had a mean conductivity of 424 µS/cm. Downstream of EFK 23.4, site EFK 13.8 had a lower mean value of 395 µS/cm. The Mitchell Branch site MIK 0.1 at ETTP had a mean conductivity value of 451 µS/cm. Mill Branch (MBK 1.6), an ecological reference site, had the lowest conductivity among all streams measured with a mean value of 255 µS/cm.

An analysis of variance (ANOVA) was performed to determine if mean conductivity differed significantly among streams. Results from the ANOVA indicated statistically significant differences with $p < 0.05$. A post hoc Tukey test was performed to distinguish which monitoring sites are significantly different in conductivity. Results of the Tukey test indicate that Bear Creek site BCK 12.3 is statistically significantly higher in conductivity than all other monitored sites with $p < 0.05$ (see Table 9.1.2). This finding is consistent with historical comparisons of these streams.

**Table 9.1.2: Results of Tukey comparison of means test for conductivity**

| Site | Mean Conductivity (µS/cm) |
|---|---|
| BCK 12.3¶ | 887.4 |
| BCK 9.6‡ | 525.8 |
| MIK 0.1‡§ | 451.0 |
| EFK 23.4*‡§ | 423.9 |
| EFK 13.8*§ | 394.7 |
| BCK 4.5*† | 344.1 |
| MBK 1.6† | 255.0 |

**, †, ‡, §, and ¶ represent statistically similar groupings defined by Tukey test with p < 0.05. If a site does not share a grouping with another site, then they are considered statistically different.*

Dissolved oxygen values were also evaluated from measurements collected July 2020 to June 2021. Mean values of dissolved oxygen ranged from 10.5 to 8.4 mg/L. East Fork Poplar Creek, site EFK 23.4, had the highest oxygen concentration among all sites. The ETTP Mitchell Branch site, MIK 0.1, had the lowest mean concentration of dissolved oxygen. In general, streams were quite similar in dissolved oxygen concentrations.

An ANOVA was performed to see if any significant differences exist among streams for dissolved oxygen concentrations. Results from the ANOVA indicated that no streams were statistically significantly different ($p < 0.05$) in dissolved oxygen concentrations. Mean dissolved oxygen concentrations for each site are shown below (Table 9.1.3).

**Table 9.1.3: Results of Tukey comparison of means test for dissolved oxygen**

| Site | Mean Dissolved Oxygen (mg/L) |
|---|---|
| EFK 23.4 | 10.5 |
| EFK 13.8 | 9.7 |
| MBK 1.6 | 9.6 |
| BCK 12.3 | 9.6 |
| BCK 4.5 | 9.6 |
| BCK 9.6 | 9.6 |
| MIK 0.1 | 8.4 |

Mitchell Branch (MIK 0.1) showed a tendency to have lower dissolved oxygen levels during the months of July through October, when the weather is hotter. For a typical stream, an increase in water temperature results in a decrease in dissolved oxygen concentrations. These higher water temperatures, which would be typical for the hotter time of year, could perhaps explain this decrease in oxygen concentrations. However, sites on EFPC, specifically EFK 23.4 and EFK 13.8, maintained higher water temperatures than Mitchell Branch for much of the year, yet these sites still maintained higher dissolved oxygen concentrations. Perhaps, in addition to water temperature, an oxygen demanding contaminant was loaded to Mitchell Branch from increased runoff during these hotter and wetter months. More research is needed to fully understand why Mitchell Branch tends to have these lower dissolved oxygen concentrations.

The field parameter of pH was analyzed for measurements collected July 2020 to June 2021. Mean pH values ranged from 7.85 to 7.41 among all sites. EFPC site EFK 23.4 had the highest pH readings in the spring months of 2021, with two readings at nearly 8.7 pH (Table 9.1.4).

**Table 9.1.4: Average pH**

| Site | Mean pH (Std. Unit) |
|---|---|
| EFK 23.4 | 7.85 |
| EFK 13.8 | 7.82 |
| MBK 1.6 | 7.75 |
| BCK 9.6 | 7.71 |
| BCK 4.5 | 7.63 |
| MIK 0.1 | 7.49 |
| BCK 12.3 | 7.41 |

Lastly, temperature data were evaluated for all sites measured July 2020 to June 2021. Mean water temperatures ranged from 17.9 to 13.9 degrees Celsius with EFPC being the warmest and Mill Branch being the coolest among all sites. An ANOVA indicated no statistically significant differences in water temperature among sites (see Table 9.1.5).

**Table 9.1.5: Average water temperatures**

| Site | Mean Temperature (°C) |
|---|---|
| EFK 23.4 | 17.9 |
| EFK 13.8 | 16.1 |
| MIK 0.1 | 15.9 |
| BCK 12.3 | 14.6 |
| BCK 4.5 | 14.6 |
| BCK 9.6 | 14.4 |
| MBK 1.6 | 13.9 |

The above-mentioned field parameter data collected July 2020 to June 2021 were also analyzed in conjunction with data collected 2005 to 2021 (Figure 9.1.3).

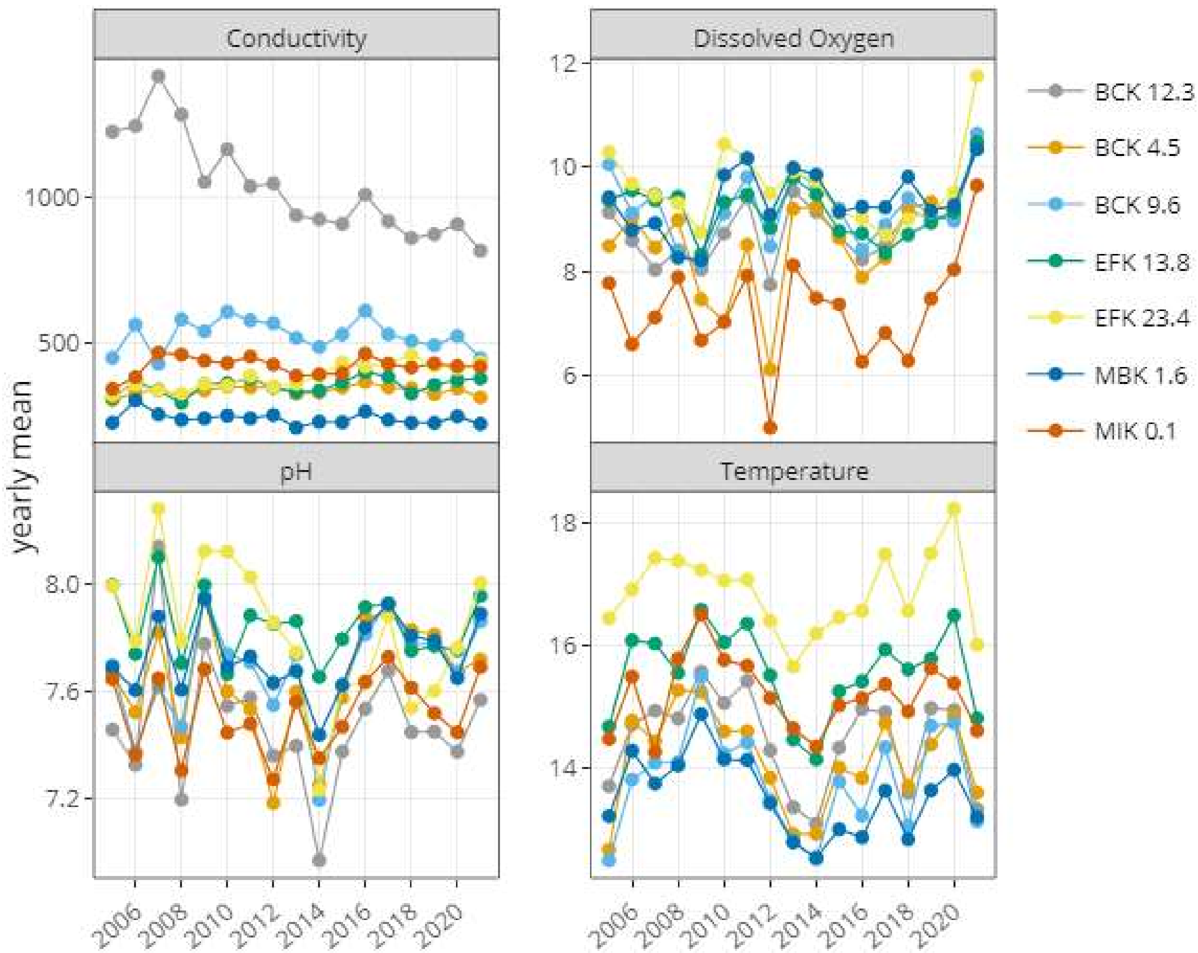


**Figure 9.1.3: Mean annual values for Conductivity, Dissolved Oxygen, pH, and Temperature from 2005 to the present for all sites. Units for conductivity, dissolved oxygen, pH, and temperature are µS/cm, mg/L, std. unit, and °C, respectively.**

Data were evaluated for significant increasing or decreasing trends with data for each parameter averaged by year. Significant linear trends with $p < 0.05$ were found for two field parameters at two different stations.

A statistically significant negative correlation was found between mean annual conductivity and time for BCK 12.3 with $p < 0.05$. This correlation was found through linear regression, with mean annual conductivity as the dependent variable and time as the independent variable. The coefficient of determination ($R^2$) was 0.788, indicating a good fit. This indicates that there is a trend of decreasing conductivity with time for site BCK 12.3. The slope of the regression line illustrates that this decrease is occurring at roughly 30 μS/cm annually. Similarly, a statistically significant positive correlation was found with mean annual conductivity and time for EFK 23.4 with $p < 0.05$. The coefficient of determination ($R^2$) was 0.748, which indicates the regression fits the data well. This trend illustrates that conductivity has increased with time since 2005 for EFK 23.4. The slope of the regression line shows that this increase is occurring at roughly 8 μS/cm annually (Figure 9.1.4).

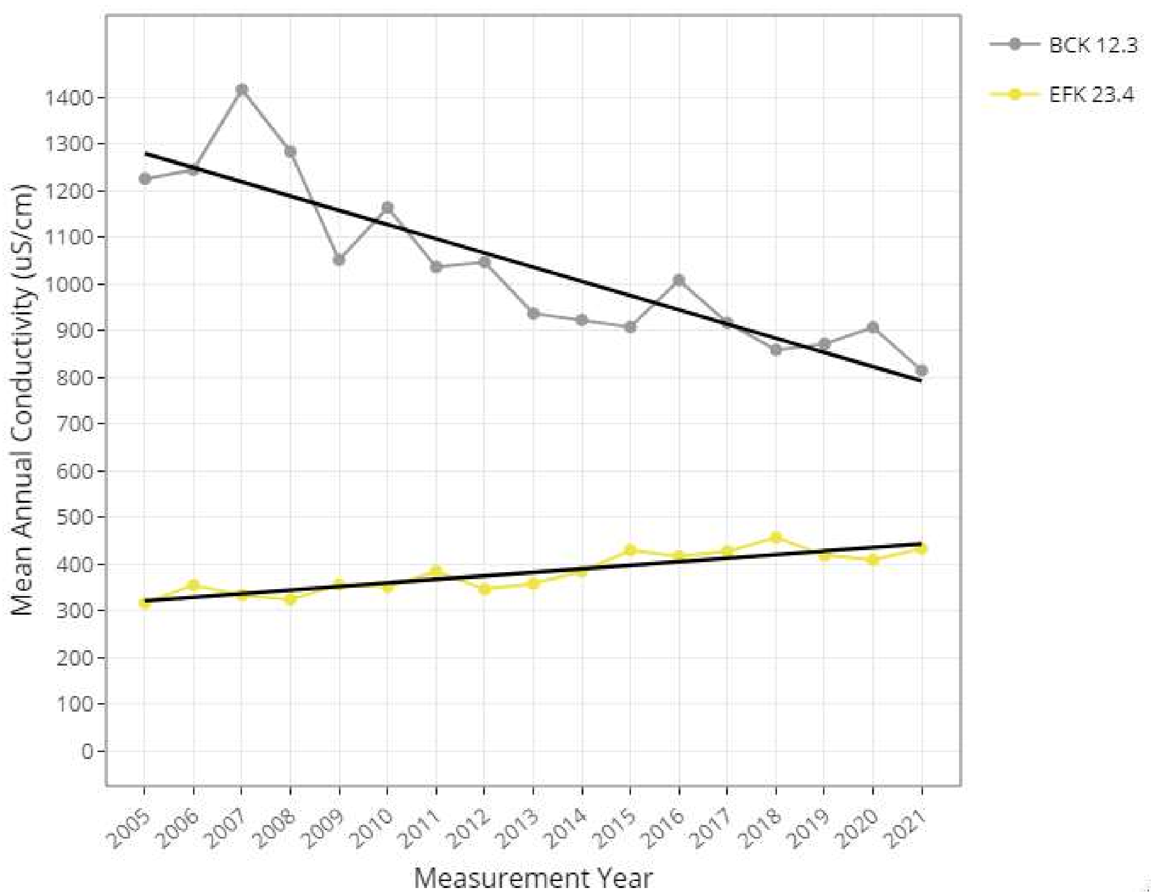


**Figure 9.1.4: Linear regression of mean annual conductivity with respect to time for sites on Bear Creek (BCK 12.3) and East Fork Poplar Creek (EFK 23.4)**

### 9.1.8 Conclusions

Field parameters including conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven monitoring locations. These data serve to populate a database and baseline for surface water conditions for many streams in the ORR as well as help to assess impact of remediation efforts and identify accidental releases.

Of these measurements, all readings were within the State of Tennessee Water Quality Criteria (TDEC, 2019). While there is no existing State of Tennessee Water Quality Criteria for conductivity, Bear Creek site BCK 12.3 was found to be statistically significantly higher than all other streams. Despite this higher conductivity, historical data (2005-2021) suggests that BCK 12.3 has a predicted decreasing trend in conductivity of roughly 32 μS/cm annually. In all, this stream is still quite high in conductivity, but is decreasing with time. This higher conductivity may be related to the proximity of this site to the capped S-3 ponds and the Y-12 West End Water Treatment Facility on the Y-12 Security Complex which contained high concentrations of metals (e.g., calcium, magnesium, sodium, potassium, and aluminum) as well as high concentrations of trace metals (Brooks, 2001). The decrease in conductivity at BCK 12.3 since 2005 may be the result of attenuation of contaminant sources in the area of the S-3 ponds and the Y-12 West End Water Treatment Facility. On East Fork Poplar Creek, site EFK 23.4 has shown a steadily increasing trend of conductivity which is on average roughly 8 μS/cm annually. The reason(s) for this increase have not yet been determined.

### 9.1.9 Recommendations

As legacy DOE ORR pollution has negatively impacted East Fork Poplar Creek, Bear Creek, and Mitchell Branch, TDEC DoR-OR recommends continued physical parameter monitoring at the seven monitoring stations in order to identify, categorize, and interpret changing trends such as the upward trend of conductivity in East Fork Poplar Creek at site EFK 23.4 and the downward trend of conductivity at Bear Creek site BCK 12.3.

### 9.1.10 References

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TDEC (2019). Rules of The Tennessee Department of Environment and Conservation, General Water Quality Criteria. Retrieved from https://publications.tnsosfiles.com/rules/0400/0400-40/0400-40-03.20190911.pdf

Turner, R. R., & Southworth, G.R. (1999). Mercury-Contaminated Industrial and Mining Sites in North America: an Overview with Selected Case Studies. In R. Ebinhaus, R. R. Turner, L. D. de Lacerda, O. Vasilev, & W. Salomons (Eds.), Environmental Science: Mercury Contaminated Sites. Springer-Verlag.

## 9.2 AMBIENT SURFACE WATER SAMPLING

### 9.2.1 Background

While legacy waste across the ORR may be responsible for a large portion of contamination to surface water, current projects and processes at these sites also have the potential to significantly contribute to surface water contamination. To help monitor potential contamination, an ambient surface water sampling project has been implemented each year since 1993. This monitoring Project originally began by investigating the water quality of the Clinch River (CR) at five (5) locations near the ORR. The sampling locations for this project have been modified throughout the years, sometimes adding, or discontinuing sampling at particular locations. Most recently, monitoring focused on five (5) primary ORR exit-pathway streams as well as the Clinch River. This project monitors surface water by sampling for contaminants in waterways that have been potentially impacted by past and present activities on the ORR.

DOE has implemented a surface water monitoring program for several years that consists of sample collection and analysis from a few locations along the Clinch River (DOE, 2017; DOE, 2019; DOE, 2020). Currently, DOE collects samples quarterly at four (4) sites along the Clinch

River at river kilometers 16, 32, 58, and 66 (Figure 9.2.1) (DOE, 2020). Of these sites, CRK 58 is near the water supply intake for Knox County, and CRK 66 is upstream of the Oak Ridge City water intake. Grab samples are collected at these four (4) sites and are analyzed for water quality parameters such as dissolved oxygen, pH, and water temperature. Samples are also screened for radioactivity by investigating gross alpha, gross beta, and gamma disintegrations. At three (3) of the four (4) sites, analyses are performed to investigate concentrations of mercury. However, mercury samples are not collected by DOE from the Knox County water supply site (CRK 58). Strontium-90 is analyzed at three (3) of the sites: at the confluence of the White Oak Creek (WOC) and Clinch River near ORNL, upstream of the Oak Ridge City water intake, and downstream of the ORR.

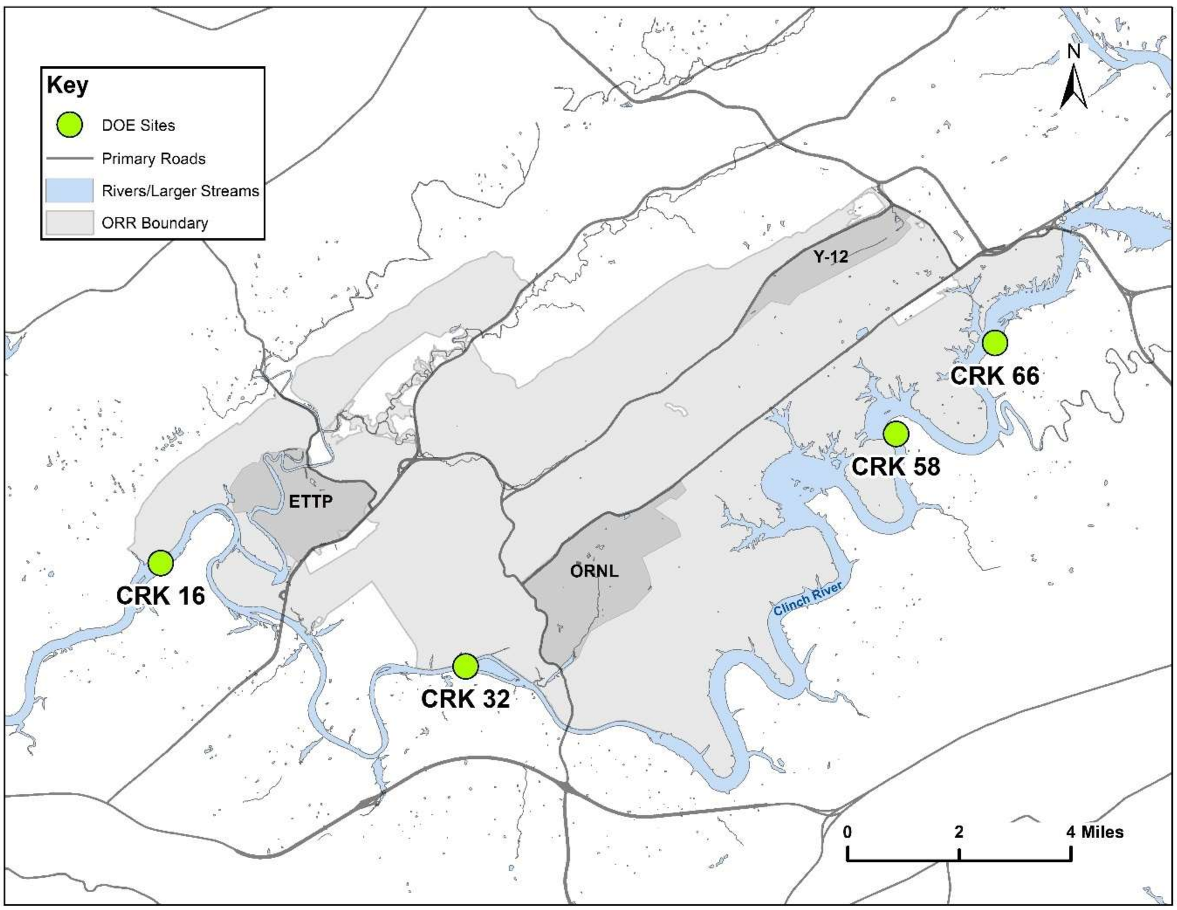


**Figure 9.2.1: Map showing current DOE sampling sites**

The purpose of the current DOE Surface Water Monitoring Project is to assess the impacts from both past and present site operations to surface water bodies as well as to assess the impact of radioactivity to human health. Respective analyte maximum contaminant levels (MCLs) as defined by the EPA are used to determine potential impacts (EPA, 2009).

While the current DOE project solely samples the Clinch River, this TDEC DoR-OR project builds upon DOE sampling by looking at specific exit-pathway streams that flow into the Clinch River. These include the ORR's Bear Creek (BC) and East Fork Poplar Creek (EFPC) as well as an offsite background stream Clear Creek (CC) which also flows to the Clinch River. The Clinch River itself was also analyzed at several locations. Samples and flow measurements were taken at these streams with the intent to provide a more representative evaluation of the loading of contaminants at each given station, ultimately which would flow to the Clinch River. Additional co-sampling was also performed at all of the DOE Clinch River sites (i.e. CRK 16, 32, 58, 66). As done by DOE, all sites were compared to criteria defined by EPA and the state of Tennessee to determine stream impact (EPA, 2009; TDEC, 2019).

### 9.2.2 Problem Statements

This project supplements DOE's study of the Clinch River to better understand impact to human health. It is estimated, based on 2017 US census data, that nearly 1.2 million people live in the counties surrounding the ORR (DOE, 2017). A large portion of these people have the potential of being influenced by streams that drain the ORR. All of the exit-pathway streams on the ORR eventually flow into the Clinch River. In turn, the Clinch River ultimately flows into the Tennessee River. Twelve water supplies are located on these rivers within 170 river miles downstream of White Oak Creek (DOE, 1992). The Clinch River alone provides drinking water as well as water for industrial use to many municipalities near and downstream of the ORR. These include Anderson County, Knox County, Roane County, the City of Clinton, the City of Kingston, the City of Norris, and the City of Oak Ridge. The Clinch River surface waters are also used for facilities at the Y-12 National Security Complex (Y-12), the Oak Ridge National Laboratory (ORNL), and the East Tennessee Technology Park (ETTP). Thus, it is important to monitor these exit pathway streams, as well as the Clinch River, to better understand the ORR's impact on this widely used resource.

As seen now and historically, these ORR exit-pathway streams and the Clinch River have been and are currently subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These releases can be detrimental to the environment and to human health.

Identified concerns include but are not limited to the following:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury to EFPC by spills and leakage from subsurface drains, building foundations, and contaminated soil, as well as purposed discharge of wastewater containing mercury (Turner and Southworth, 1999).

- EFPC is believed to contribute approximately 0.2 metric tons of mercury to the Clinch

River each year (DOE, 1992).

- In addition to mercury, other metals that have been found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver, and zirconium (DOE, 1992).

- Regarding Bear Creek, DOE has stated, “The primary contaminants in the surface water are uranium, nitrate, and cadmium. The S-3 site currently contributes approximately 26% of the risk at the [Bear Creek Valley] Watershed Integration Point through releases of uranium” (DOE, 1999).

Monitoring ORR exit-pathway streams helps TDEC to assess which ORR facilities may be contributing to surface water pollution. This monitoring provides insight to help protect human health and the environment from potential ORR surface water pollution.

### 9.2.3 Goals

The goal of this ambient surface water monitoring project is to evaluate the impact of contamination from two (2) major ORR exit-pathway streams (Bear Creek and East Fork Poplar Creek). The Clinch River will also be monitored in conjunction with DOE sampling (see Figure 9.2.2). Clear Creek will be used as a background comparison stream as it also flows to the Clinch River, but offsite of the ORR (see Figure 9.2.2). This project ultimately seeks to understand each respective stream’s contribution or loading of contaminants to the Clinch River. An assessment of each stream’s impact, including the Clinch River, will be performed by comparing results to EPA defined maximum contaminant levels (EPA, 2009). In all, this project will help to define areas of concern on the ORR that may be significantly impacting the surface water resources of Tennessee citizens.

To accomplish this goal, several objectives were completed. These objectives include:

1. Collect surface water samples quarterly at two (2) ORR exit-pathway streams, one (1) ORR background stream, and the Clinch River (Figure 9.2.3).
    - Bear Creek (BCK): sample three (3) locations at BCK 12.3, BCK 9.6, and BCK 3.3 for uranium, mercury, and major cations/anions.

    - East Fork Poplar Creek (EFK): sample five (5) locations at EFK 25.1, EFK 24.4, EFK 23.4, EFK13.8, and EFK 6.3 for uranium, mercury, and major cations/anions.

    - Clear Creek (CCK): sample one (1) location at CCK 1.6 for uranium, mercury, and major cations/anions. This information was used as a background comparison stream to the ORR streams.

- Clinch River (CRK): co-sampled with UT-Battelle quarterly at one (1) of the four (4) sites CRK 66, CRK 58, CRK 32, and CRK 16.1 with each site sampled at least once throughout the project. These sites were sampled for gross alpha/beta, mercury, and strontium-89,90.

2. Measure physical water parameters (e.g. conductivity, dissolved oxygen, pH, and temperature) at each site at time of sampling.
3. Measure stream flow rates at the time of sampling (excluding the CR sites).

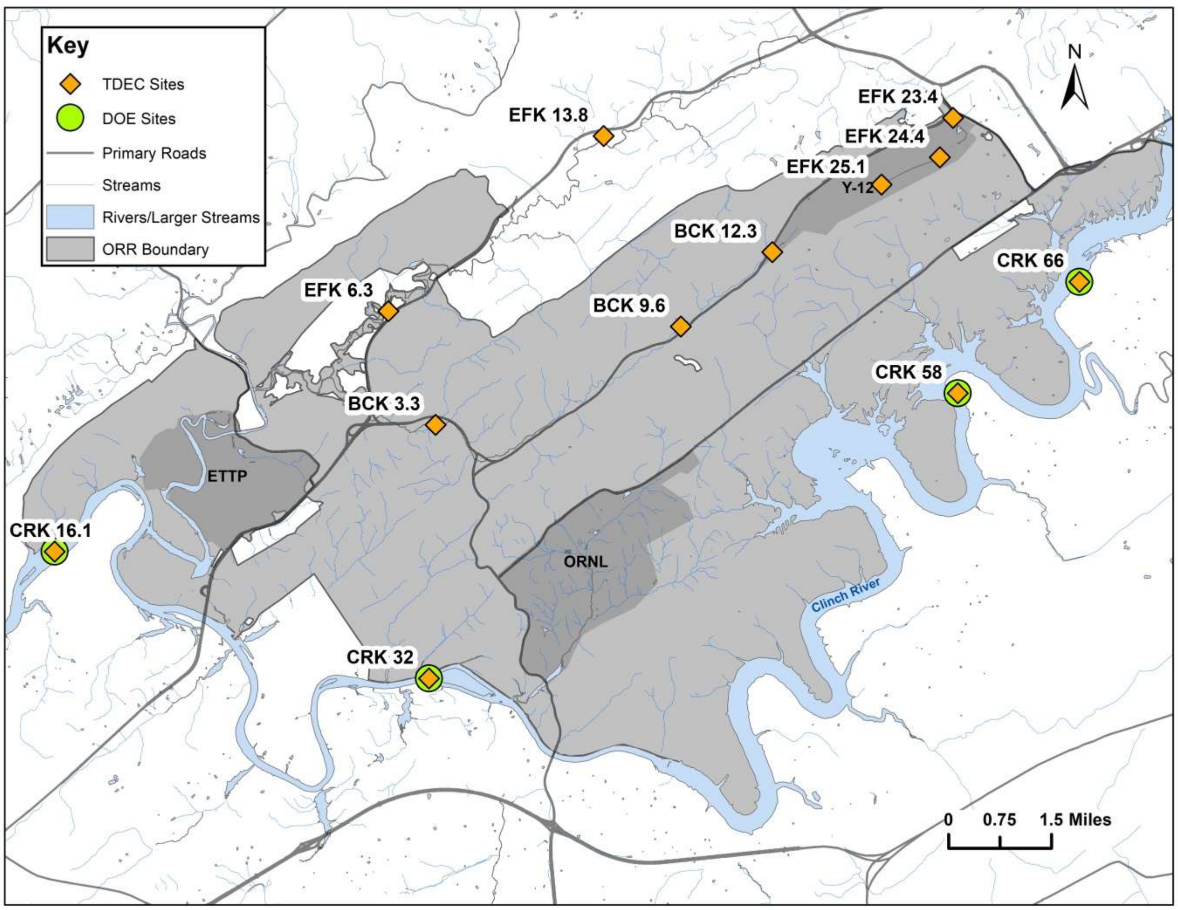


**Figure 9.2.2: Map showing TDEC DoR-OR and DOE sampling sites on the ORR**

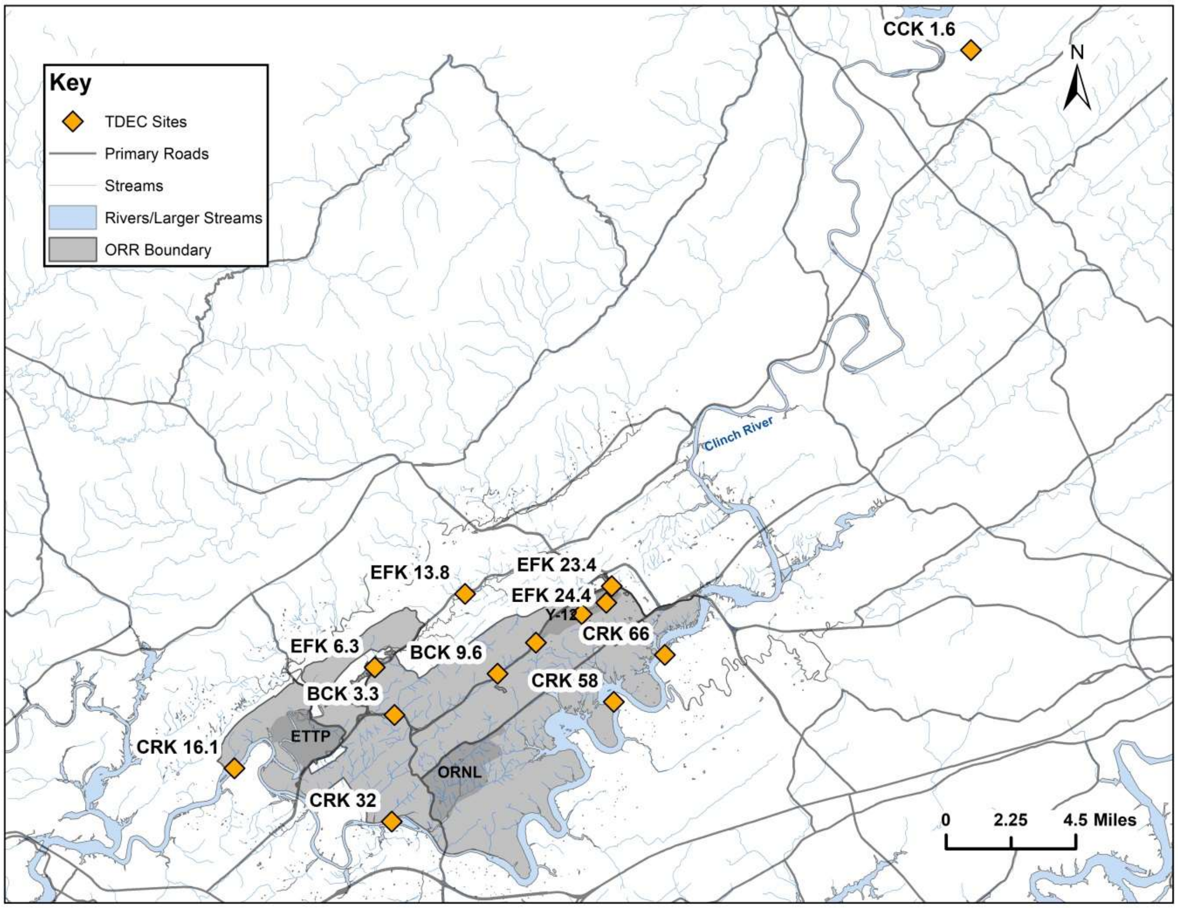


**Figure 9.2.3: Zoomed out map showing proposed TDEC DoR-OR sampling sites including the CC background site. The number associated with each site represents the distance in kilometers from the mouth of the stream or river to that location.**

## 9.2.4 Scope

The scope of this project was to characterize stream conditions and assess contaminant flux through sampling, stream flow measurements, and analysis of surface water from two (2) ORR exit-pathway streams and (1) background stream, all of which flow into the CR. A segment of the CR was also assessed spanning from the Oak Ridge City water intake at CRK 66 downstream to CRK 16.1 which is downstream of all ORR exit stream inputs.

## 9.2.5 Methods, Materials, Metrics

*Sample Collection*

Surface water samples were collected quarterly at three (3) sites on BC, one (1) site on CC (background stream), and five (5) sites on EFPC. Each quarter, one (1) of four (4) CR sites was co-sampled, with each CR site being sampled once throughout the project. Samples from BC, CC, and EFPC were sampled and analyzed for metals such as mercury and uranium, inorganic cations such as sodium, potassium, calcium, and magnesium, and inorganic anions including fluoride, chloride, sulfate, phosphorus, and nitrate. Samples collected from the CR sites were analyzed for gross alpha, gross beta, mercury, and strontium-90 (Table 9.2.1). Sampling protocols followed the Tennessee Department of Environment and Conservation Division of Water Resources Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water (TDEC, 2018).

**Table 9.2.1: Site locations, descriptions, and list of analytes**

| | | | Planned Sampling | | | | |
|---|---|---|---|---|---|---|---|
| DoR-OR Site | Latitude | Longitude | Rads | Uranium | Mercury | Major Cation | Major Anion |
| CRK 16.1 | 35.92186 | -84.42942 | 1 | | 1 | | |
| CRK 32 | 35.9002 | -84.35049 | 1 | | 1 | | |
| CRK 58 | 35.94891535 | -84.23902273 | 1 | | 1 | | |
| CRK 66 | 35.967958 | -84.213382 | 1 | | 1 | | |
| BCK 12.3 | 35.973 | -84.27814 | | 4 | 4 | 4 | 4 |
| BCK 9.6 | 35.96032 | -84.29741 | | 4 | 4 | 4 | 4 |
| BCK 3.3 | 35.94354 | -84.34911 | | 4 | 4 | 4 | 4 |
| EFK 25.1 | 35.98456 | -84.2551 | | 4 | 4 | 4 | 4 |
| EFK 24.4 | 35.98922 | -84.24282 | | 4 | 4 | 4 | 4 |
| EFK 23.4 | 35.99596 | -84.24004 | | 4 | 4 | 4 | 4 |
| EFK 13.8 | 35.99283 | -84.31371 | | 4 | 4 | 4 | 4 |
| EFK 6.3 | 35.96293 | -84.35905 | | 4 | 4 | 4 | 4 |
| CCK 1.6 | 36.21346 | -84.05983 | | 4 | 4 | 4 | 4 |
| Field Blank | | | | 1 | 1 | 1 | 1 |
| Field Duplicate | | | 1 | 4 | 4 | 4 | 4 |

| |
|---|
| DOE Co-Sample |
| Ambient |
| QA/QC |

**Note:**
Rads: gross a/b, Sr-90
Major Cation: sodium, potassium, calcium, magnesium
Major Anion: fluoride, chloride, sulfate, total phosphorus, nitrate/nitrite, total alkalinity

*Field Parameter Measurements*

At each site, physical water parameters were collected during the time of sampling. Physical parameters were measured using a multiple parameter water quality meter. Parameters of conductivity (µS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) were recorded along with time of measurement.

*Stream Flow Measurements*

Stream flow measurements were taken at each stream at the time of sampling. This was accomplished by measuring the cross-sectional transect perpendicular to the flow of the stream as well as measuring the flow rate using a FlowTracker2® instrument. The FlowTracker2® instrument allows for an accurate measurement of a stream's cross-section. Results from the flow measurements were implemented into Sontek Flowtracker software to best characterize the stream flow. Clinch River sites were excluded from stream flow measurements.

### 9.2.6 Deviations from the Plan

A few deviations from the plan occurred. For specific deviations, see Table 9.2.2 below.

**Table 9.2.2: Description of deviations from plan by quarter (e.g. Q1 = 1st quarter)**

| DOE-O Site Description | DoR-OR Site | Variance |
|---|---|---|
| Bear Creek Mile 7.6 | BCK 12.3 | Q1: pooling no measureable flow |
| Bear Creek Mile 6.0 | BCK 9.6 | Q1: pooling no measureable flow |

### 9.2.7 Results and Analysis

Samples were collected at sites quarterly. Data summaries of sampled constituents are shown below. See tables 9.2.3 and 9.2.4 for quarterly sampling results. Table values highlighted in orange indicate exceedance of the TN water quality mercury criteria of 0.05 µg/L for TN water and organisms or the EPA drinking water MCL of 30 µg/L for uranium. A yellow highlight indicates that a value is close to the MCL, within rounding. While drinking water may not be an end use in these streams, it provides a reference for uranium contamination. Major anions and cations were also collected for these sites and are illustrated in Figures 9.2.4 – 9.2.7.

## Table 9.2.3: Results from ORR streams

| DOE-O Site Description | DoR-OR Site | Uranium (ug/L) | Mercury (ug/L) | Discharge (L/s) | Temperature (C) | pH | Dissolved Oxygen (mg/L) | Conductivity (uS/cm) | Date | Quarter |
|---|---|---|---|---|---|---|---|---|---|---|
| Bear Creek Mile 7.6 | BCK 12.3 | 220.00 | 0.00181 | * | 19.7 | 7.38 | 8.0 | 1058 | 9/15/2020 | 1 |
| Bear Creek Mile 7.6 | BCK 12.3 | 182.00 | 0.00527 | 2.20 | 9.2 | 7.47 | 10.9 | 709 | 11/18/2020 | 2 |
| Bear Creek Mile 7.6 | BCK 12.3-Dup | 182.00 | 0.00636 | 2.20 | 9.2 | 7.47 | 10.9 | 709 | 11/18/2020 | 2 |
| Bear Creek Mile 7.6 | BCK 12.3 | 109.00 | 0.00604 | 12.15 | 7.4 | 7.25 | 12.8 | 564 | 2/24/2021 | 3 |
| Bear Creek Mile 7.6 | BCK 12.3 | 141.00 | 0.00666 | 5.86 | 16.0 | 7.76 | 9.0 | 857 | 5/18/2021 | 4 |
| Bear Creek Mile 6.0 | BCK 9.6 | 51.10 | 0.00436 | * | 20.2 | 7.82 | 6.2 | 640 | 9/15/2020 | 1 |
| Bear Creek Mile 6.0 | BCK 9.6 | 52.50 | 0.00578 | 8.68 | 8.9 | 7.62 | 11.1 | 536 | 11/18/2020 | 2 |
| Bear Creek Mile 6.0 | BCK 9.6 | 29.70 | 0.00453J | 68.11 | 7.3 | 7.64 | 13.7 | 378 | 2/24/2021 | 3 |
| Bear Creek Mile 6.0 | BCK 9.6 | 26.50 | 0.00610 | 26.40 | 16.8 | 8.17 | 9.3 | 392 | 5/18/2021 | 4 |
| Bear Creek Mile 2.0 | BCK 3.3 | 10.30 | 0.00188 | 38.53 | 19.7 | 7.89 | 7.7 | 407 | 9/15/2020 | 1 |
| Bear Creek Mile 2.0 | BCK 3.3 | 16.00 | 0.0029J | 103.43 | 8.4 | 7.68 | 11.6 | 346 | 11/18/2020 | 2 |
| Bear Creek Mile 2.0 | BCK 3.3 | 10.90 | 0.00337J | 409.18 | 8.0 | 7.60 | 12.9 | 223 | 2/24/2021 | 3 |
| Bear Creek Mile 2.0 | BCK 3.3 | 11.50 | 0.00197 | 138.52 | 16.0 | 8.25 | 9.9 | 309 | 5/18/2021 | 4 |
| East Fork Poplar Creek Mile 15.6 | EFK 25.1 | 11.30 | 1.09000 | 37.45 | 27.3 | 6.97 | 5.8 | 395 | 9/9/2020 | 1 |
| East Fork Poplar Creek Mile 15.6 | EFK 25.1 | 60.60 | 0.38400 | 45.02 | 23.1 | 7.60 | 7.3 | 558 | 11/4/2020 | 2 |
| East Fork Poplar Creek Mile 15.6 | EFK 25.1 | 41.40 | 0.54400 | 81.99 | 15.3 | 8.01 | 9.5 | 750 | 3/8/2021 | 3 |
| East Fork Poplar Creek Mile 15.6 | EFK 25.1 | 34.30 | 0.60000 | 34.11 | 25.3 | 7.82 | 6.8 | 390 | 5/25/2021 | 4 |
| East Fork Poplar Creek Mile 15.6 | EFK 25.1- Dup | 34.00 | 0.77700 | 34.11 | 25.3 | 7.82 | 6.8 | 390 | 5/25/2021 | 4 |
| East Fork Poplar Creek Mile 15.2 | EFK 24.4 | 11.50 | 0.30200 | 68.35 | 23.6 | 7.38 | 7.0 | 432 | 9/9/2020 | 1 |
| East Fork Poplar Creek Mile 15.2 | EFK 24.4 | 37.70 | 0.29200 | 93.11 | 16.7 | 7.60 | 8.6 | 493 | 11/4/2020 | 2 |
| East Fork Poplar Creek Mile 15.2 | EFK 24.4 | 56.00 | 0.31200 | 80.15 | 12.7 | 8.23 | 11.4 | 751 | 3/8/2021 | 3 |
| East Fork Poplar Creek Mile 15.2 | EFK 24.4-Dup | 56.50 | 0.33200 | 80.15 | 12.7 | 8.23 | 11.4 | 751 | 3/8/2021 | 3 |
| East Fork Poplar Creek Mile 15.2 | EFK 24.4 | 23.20 | 0.52900 | 61.74 | 21.4 | 7.96 | 7.7 | 461 | 5/25/2021 | 4 |
| East Fork Poplar Creek Mile 14.5 | EFK 23.4 | 9.55 | 0.15200 | 54.12 | 23.0 | 7.94 | 9.3 | 391 | 9/9/2020 | 1 |
| East Fork Poplar Creek Mile 14.5 | EFK 23.4-Dup | 9.92 | 0.16400 | 54.12 | 23.0 | 7.94 | 9.3 | 391 | 9/9/2020 | 1 |
| East Fork Poplar Creek Mile 14.5 | EFK 23.4 | 28.70 | 0.18100 | 110.06 | 16.1 | 8.04 | 10.7 | 336 | 11/4/2020 | 2 |
| East Fork Poplar Creek Mile 14.5 | EFK 23.4 | 39.00 | 0.21200 | 100.18 | 12.0 | 8.67 | 13.5 | 432 | 3/8/2021 | 3 |
| East Fork Poplar Creek Mile 14.5 | EFK 23.4 | 16.10 | 0.24600 | 62.35 | 20.9 | 8.63 | 10.4 | 426 | 5/25/2021 | 4 |
| East Fork Poplar Creek Mile 8.6 | EFK 13.8 | 8.69 | 0.16800 | 118.28 | 21.6 | 7.85 | 8.1 | 406 | 9/9/2020 | 1 |
| East Fork Poplar Creek Mile 8.6 | EFK 13.8 | 15.80 | 0.02950 | 244.05 | 11.2 | 7.93 | 11.0 | 429 | 11/4/2020 | 2 |
| East Fork Poplar Creek Mile 8.6 | EFK 13.8 | 12.50 | 0.02910 | 393.99 | 9.1 | 8.29 | 12.4 | 355 | 3/8/2021 | 3 |
| East Fork Poplar Creek Mile 8.6 | EFK 13.8 | 9.43 | 0.02860 | 201.21 | 20.1 | 8.09 | 8.1 | 399 | 5/25/2021 | 4 |
| East Fork Poplar Creek Mile 3.9 | EFK 6.3 | 4.24 | 0.06400 | 276.85 | 22.0 | 7.85 | 7.9 | 417 | 9/9/2020 | 1 |
| East Fork Poplar Creek Mile 3.9 | EFK 6.3 | 8.87 | 0.02590 | 513.33 | 12.1 | 7.80 | 10.3 | 448 | 11/4/2020 | 2 |
| East Fork Poplar Creek Mile 3.9 | EFK 6.3 | 5.83 | 0.02520 | 919.74 | 9.7 | 8.22 | 12.6 | 334 | 3/8/2021 | 3 |
| East Fork Poplar Creek Mile 3.9 | EFK 6.3 | 4.66 | 0.03280 | 377.19 | 20.5 | 8.00 | 7.7 | 403 | 5/25/2021 | 4 |
| Clear Creek Mile 1.0 | CCK 1.6 | 0.256J | 0.00088 | 18.52 | 14.6 | 7.59 | 9.4 | 283 | 9/23/2020 | 1 |
| Clear Creek Mile 1.0 | CCK 1.6 | 0.263J | 0.00122J | 33.89 | 8.7 | 7.26 | 11.0 | 281 | 12/8/2020 | 2 |
| Clear Creek Mile 1.0 | CCK 1.6 | 0.16J | 0.00105J | 60.37 | 12.3 | 7.94 | 9.9 | 232 | 3/16/2021 | 3 |
| Clear Creek Mile 1.0 | CCK 1.6 | 0.219J | U | 31.99 | 14.8 | 7.87 | 9.3 | 266 | 6/2/2021 | 4 |

## Table 9.2.4: Results from Clinch River Sampling

| DOE-O Site Description | DoR-OR Site | Sr-89 (pCi/L) | Sr-90 (pCi/L) | Gross α (pCi/L) | Gross ß (pCi/L) | Mercury (ug/L) | Temperature (C) | pH | Dissolved Oxygen (mg/L) | Conductivity (uS/cm) | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Clinch River Mile 10.0 | CRK 16.1 | pending | pending | pending | pending | 0.00537 | 22.80 | 8.02 | 7.62 | 287.50 | 6/21/2021 |
| Clinch River Mile 19.7 | CRK 32 | 1.80 | 1.33 | 0.17 | 0.60 | 0.00147 | 8.9 | 8.30 | 12.1 | * | 3/11/2021 |
| Clinch River Mile 19.7 | CRK 32-Dup | 2.50 | 1.90 | 0.41 | 1.60 | * | 8.9 | 8.30 | 12.1 | * | 3/11/2021 |
| Clinch River Mile 36.0 | CRK 58 | -0.19 | 0.95 | 0.23 | 0.40 | pending | 17.9 | 7.34 | 5.65 | 276 | 10/26/2020 |
| Clinch River Mile 41.0 | CRK 66 | 0.60 | 0.49 | 0.41 | 3.60 | 0.00169 | 26.4 | 7.84 | 10.9 | 219 | 8/31/2020 |

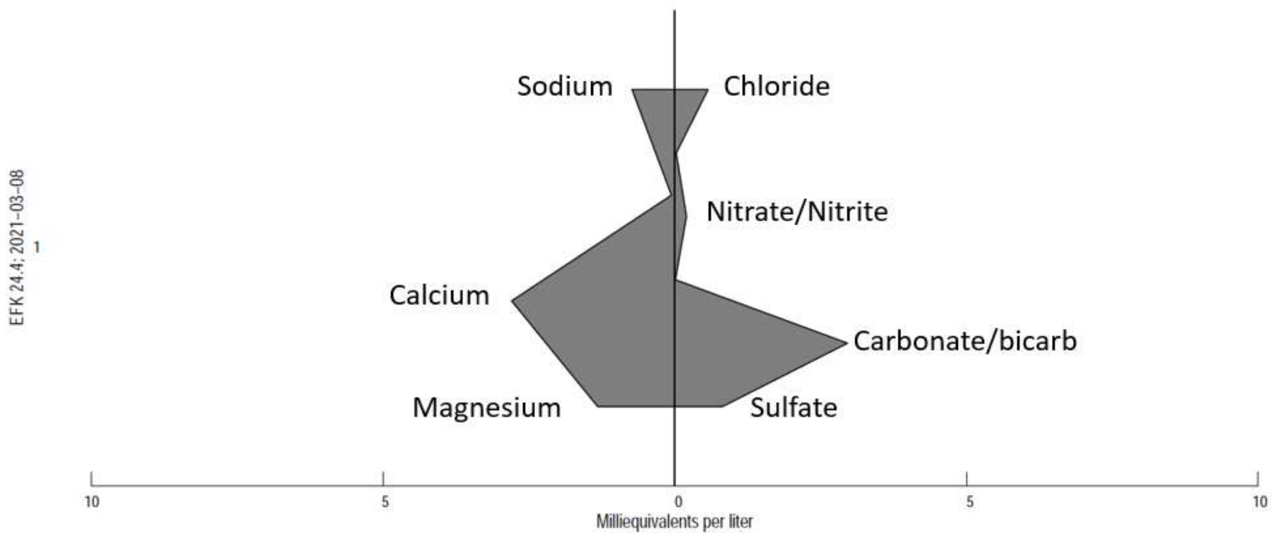


**Figure 9.2.4: Typical East Fork Poplar Creek stiff plot. This plot shows EFK 24.4 on 3/8/2021 in milliequivalents per liter. Note the predominately calcium carbonate water signature.**

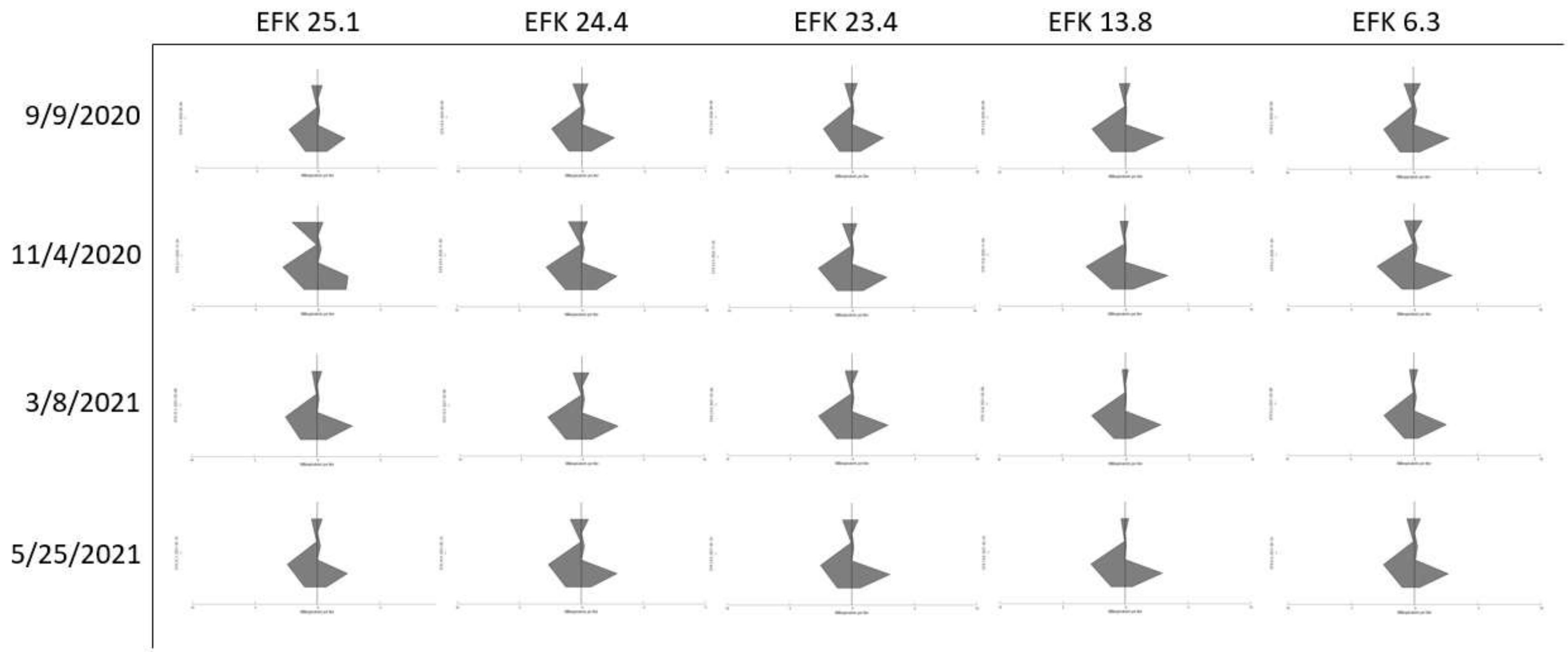


**Figure 9.2.5: East Fork Poplar Creek stiff plots in milliequivalents per liter for four sampling events. Nodes on left side of stiff plot axis from top to bottom include sodium, potassium, calcium, and magnesium. Nodes on the right side of axis from top to bottom include chloride, fluoride, nitrates, phosphate, carbonate/bicarbonate, and sulfate. A predominant calcium bicarbonate water is shown at all sampling events with a fair amount of magnesium. A small amount of sodium, chloride, and sulfate are also present.**

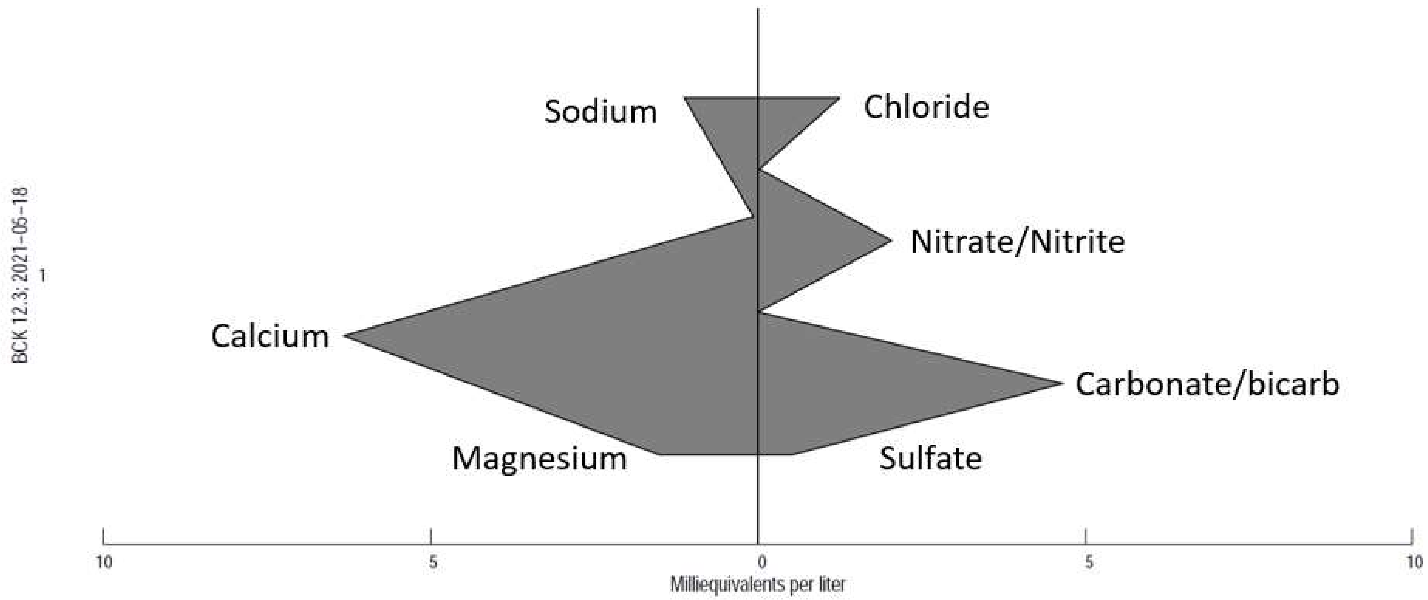


**Figure 9.2.6: Stiff plot from Bear Creek 12.3 on 5/18/2021 in milliequivalents per liter. Note the predominately calcium carbonate water signature with a fair amount of nitrates.**

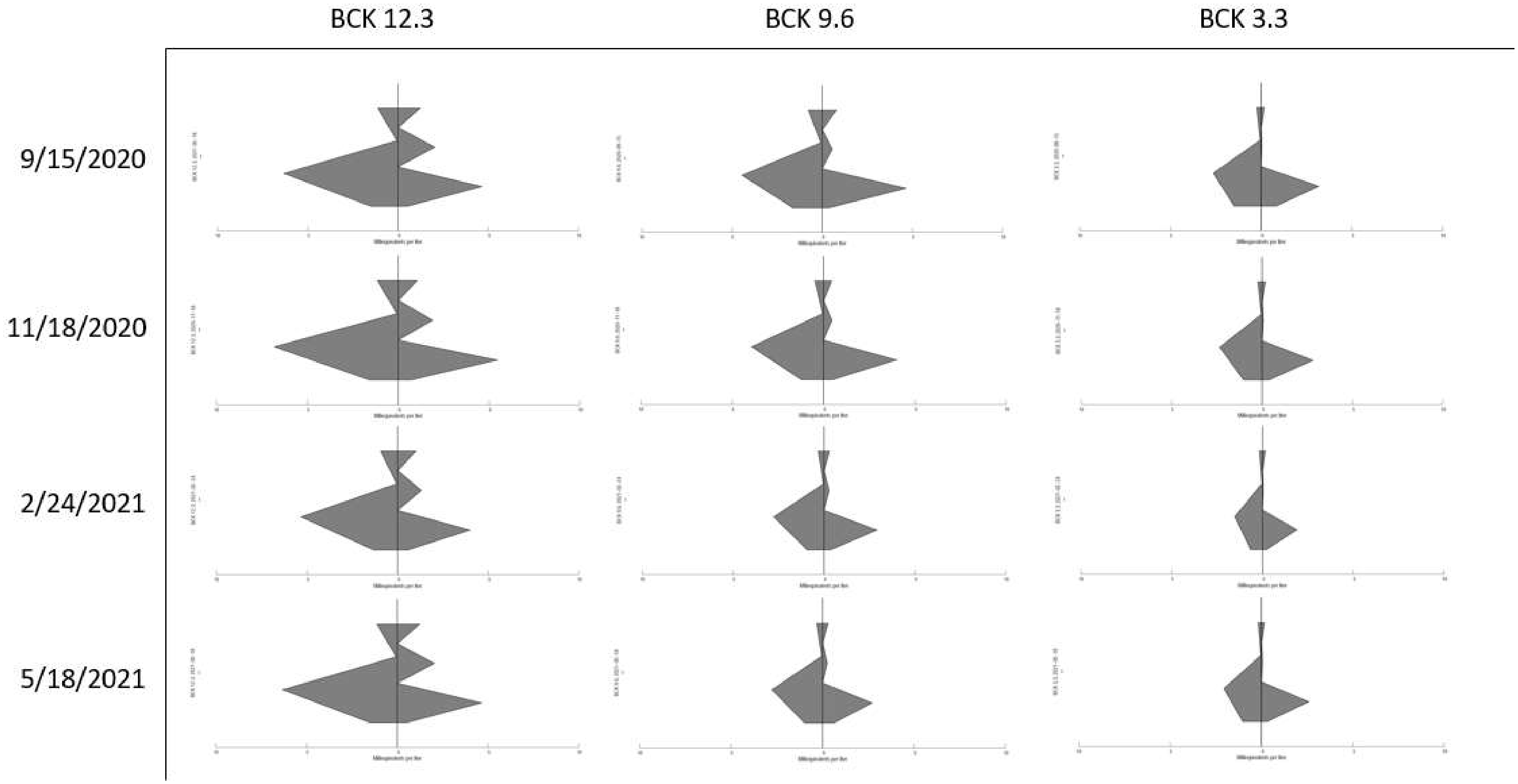


**Figure 9.2.7: Bear Creek stiff plots in milliequivalents per liter for four sampling events. Nodes on left side of stiff plot axis from top to bottom include sodium, potassium, calcium, and magnesium. Nodes on the right side of axis from top to bottom include chloride, fluoride, nitrates, phosphate, carbonate/bicarbonate, and sulfate. A predominant calcium bicarbonate water is shown at all sampling events with a fair amount of nitrates. A small amount of sodium, chloride, and sulfate are also present. Dilution occurs from BCK 12.3 to downstream sites for all cations and anions.**

*Stream Flow*

Stream flow was measured at several locations along the exit-pathway streams. Flow measurements were taken each quarter (four times) at most sites. Due to pooling conditions in the September 2020 sampling event (see Table 9.2.2), sites BCK 12.3 and BCK 9.6 were not measured. However, flow measurements were taken on all other sampling dates. Of these flow measurements at each site, EFK 6.3 had the highest average flow of 521.8 L/s and BCK 12.3 had the lowest mean flow at 6.7 L/s. The maximum flows for most sites occurred in late February and early March based on the limited measurements taken. EFK 24.4 and 23.4 both had higher flows in the November measurement but are comparable to their respective March measurements. Descriptive statistics of the flow measurements are shown below in Table 9.2.5 and Figure 9.2.8.

**Table 9.2.5: Flow Measurements in Liters per Second**

| Station | Min. Flow | Max Flow | Mean Flow | Quarters Measured |
|---|---|---|---|---|
| BCK 12.3 | ponding | 12.2 | 6.7 | 3 |
| BCK 9.6 | ponding | 68.1 | 34.4 | 3 |
| BCK 3.3 | 38.5 | 409.2 | 172.4 | 4 |
| EFK 25.1 | 34.1 | 82.0 | 49.6 | 4 |
| EFK 24.4 | 61.7 | 93.1 | 75.8 | 4 |
| EFK 23.4 | 54.1 | 110.1 | 81.7 | 4 |
| EFK 13.8 | 201.2 | 394.0 | 239.4 | 4 |
| EFK 6.3 | 276.9 | 919.7 | 521.8 | 4 |
| CCK 1.6 | 18.5 | 60.4 | 36.2 | 4 |

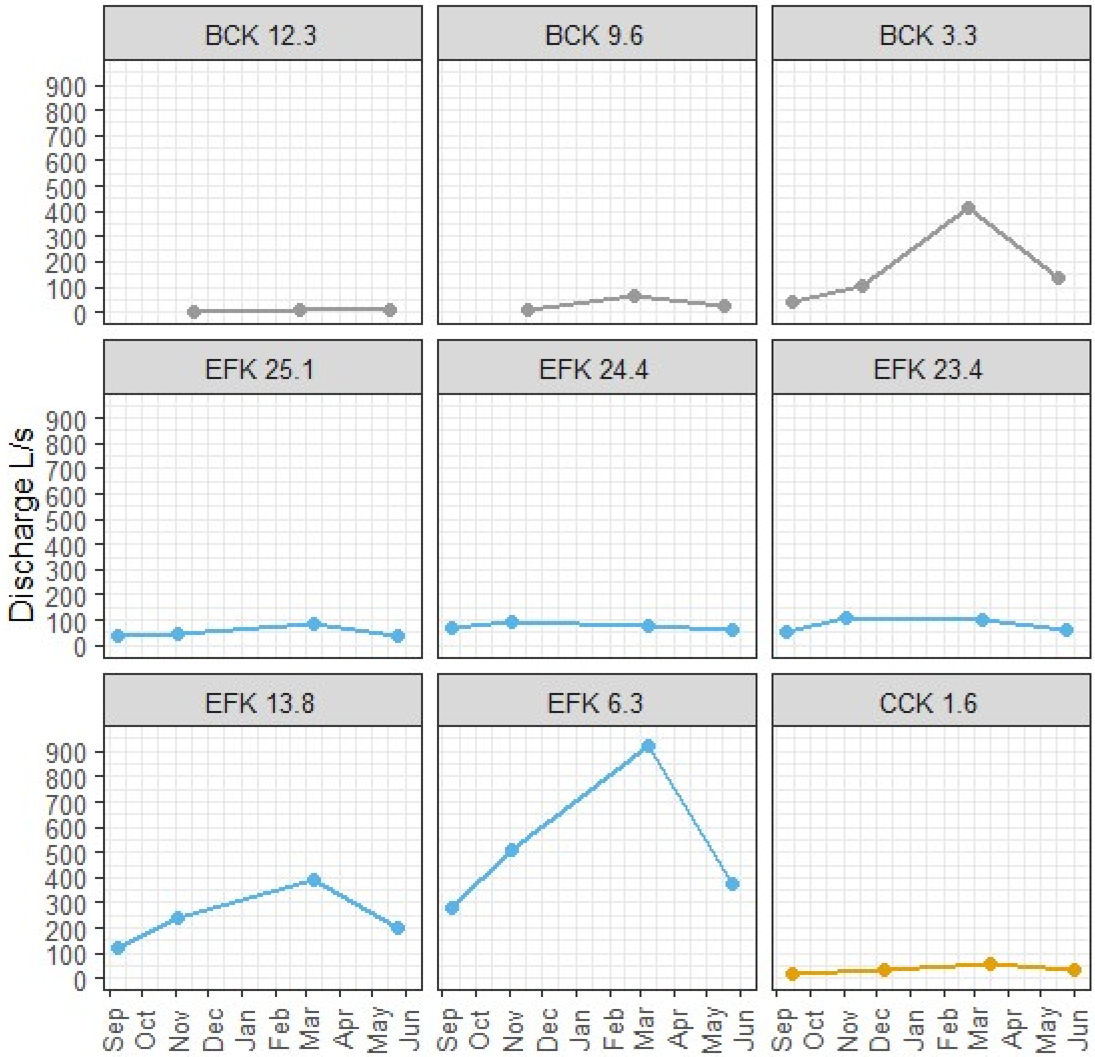


**Figure 9.2.8: Flow measurements for each station in L/s**

*Contaminant Flux*

With stream flow measurements and complementary mercury and uranium concentrations for each site, contaminant flux was able to be calculated to give an approximated mass per year loaded from each site along each stream. This represents the amount of contaminant mass passing by each site and does not necessarily equate to the amount of mass loaded into the Clinch River. While this approach provides some insight to Clinch River loading, it is better suited to understand the amount of mass passing by each site. To approximate mass passing by each site, flow measurements were multiplied by the concurrent contaminant concentration to get a mass per time. Each of the three to four measurements taken throughout the year (measurements taken in roughly September, November, March, and

June) were averaged to get an average mass per year value. These averaged values are only approximate as they are based on only a few measurements and samples. Actual results could be higher or lower if more measurements and samples were taken. Storm events that were not captured as well as any missed liberation of contaminants in these limited sampling events may provide significant differences in total contaminant flux compared to these approximations. However, these values can provide insight into possible loading potential to the Clinch River from each stream as well as provide an approximation of how much of a contaminant passes by each station in a given year. Also, it should be noted that these data below suggest the grams per year that flow past a site. This does not mean that the contaminant is originated from that site, but rather that it passes by. The only exceptions are sites BCK 12.3 and EFK 25.1, which are essentially the head waters of the respective streams. High concentrations and flux at these locations would suggest that contamination likely originates at or near those sites.

Mercury flux was able to be calculated to give an approximated mass per year loaded at each site. EFK 25.1 has the highest flux of mercury based on available data. It potentially loads an approximated 1 kilogram of mercury each year past the site location. In contrast, Clear Creek kilometer 1.6 loads approximately 1 gram of mercury each year (Table 9.2.6). East Fork Poplar Creek starts with a high mercury value at the headwaters and the flux decreases when moving downstream. Thus, it is likely that mercury is either lost to groundwater or is sorbed to creek sediment.

**Table 9.2.6: Approximated Mercury Flux**

| Station | Grams Mercury/Year | Kilograms Mercury/Year | N |
|---|---|---|---|
| BCK 12.3 | 1 | 0.001 | 3 |
| BCK 9.6 | 5 | 0.005 | 3 |
| BCK 3.3 | 16 | 0.016 | 4 |
| EFK 25.1 | 1019 | 1.019 | 4 |
| EFK 24.4 | 844 | 0.844 | 4 |
| EFK 23.4 | 515 | 0.515 | 4 |
| EFK 13.8 | 349 | 0.349 | 4 |
| EFK 6.3 | 525 | 0.525 | 4 |
| CCK 1.6 | 1 | 0.001 | 4 |

**Note: mass per year approximations represent the amount of mass passing each site. Summations of loading at each site do not represent the cummulative flux per year for the stream. Rather, the total mass leaving a stream is best estimated from the most downstream sampling location.**

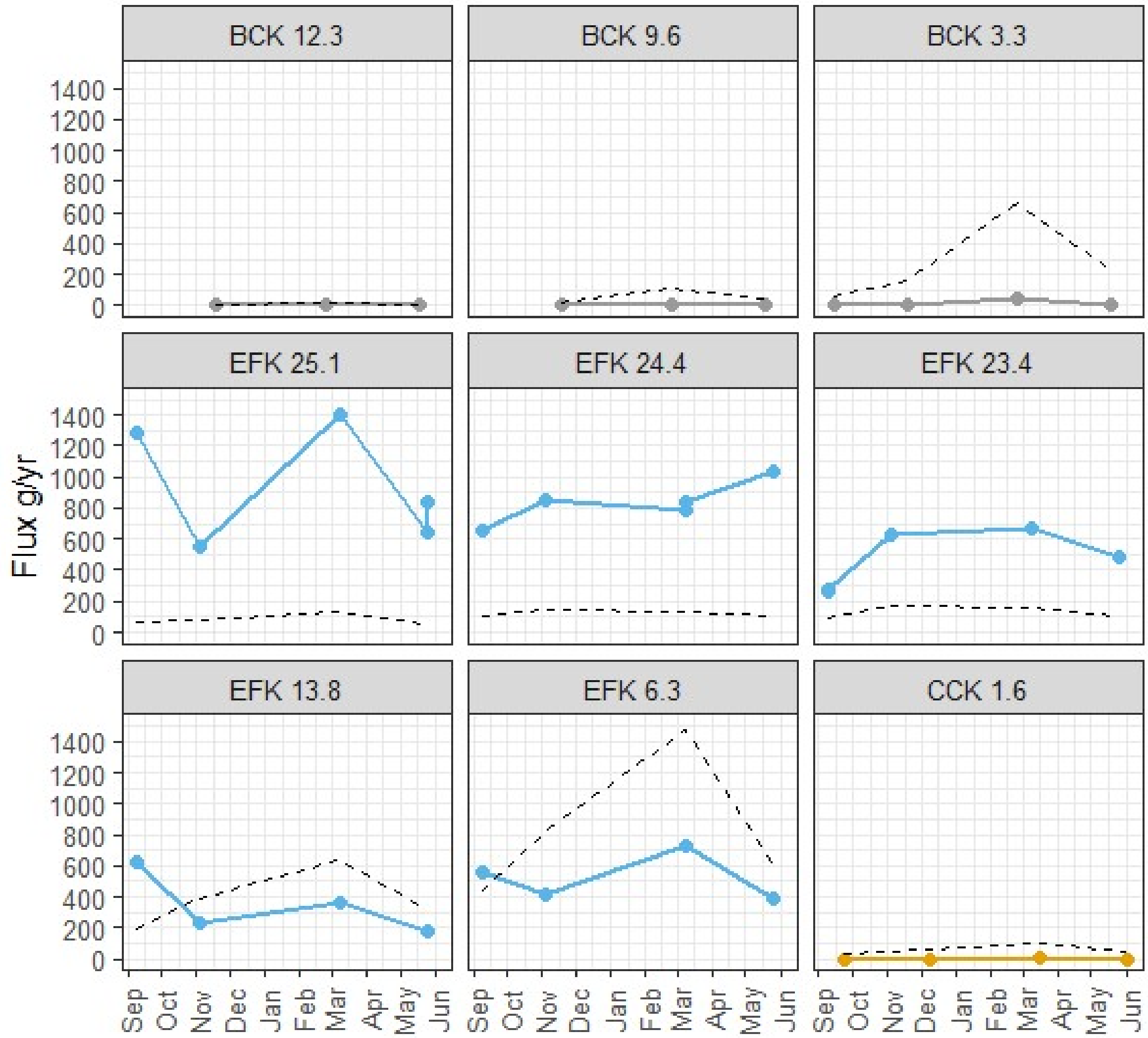


**Figure 9.2.9: Mercury flux for each station in g/yr. The dashed black line indicates the flux allowed based on the TN criteria for water and organisms when using flow measured at time of sampling (i.e., TN water quality criteria value multiplied by measured flow).**

Uranium flux was also approximated for each stream location. Bear Creek generally has higher concentrations of uranium. However, due to the lower flow at Bear Creek, East Fork Poplar Creek may potentially pass a larger mass of uranium by each site. An approximated 100 kilograms of uranium passes through East Fork Poplar Creek each year at the most downstream sampled location (EFK 6.3). In comparison, Clear Creek has a flux of only 0.2 kilograms of uranium each year (Table 9.2.7).

**Table 9.2.7: Approximated Uranium Flux**

| Station | Grams Uranium/Year | Kilograms Uranium/Year | N |
|---|---|---|---|
| BCK 12.3 | 26,811 | 26.8 | 3 |
| BCK 9.6 | 33,414 | 33.4 | 3 |
| BCK 3.3 | 63,907 | 63.9 | 4 |
| EFK 25.1 | 60,755 | 60.8 | 4 |
| EFK 24.4 | 80,878 | 80.9 | 4 |
| EFK 23.4 | 67,861 | 67.9 | 4 |
| EFK 13.8 | 92,302 | 92.3 | 4 |
| EFK 6.3 | 101,297 | 101.3 | 4 |
| CCK 1.6 | 239 | 0.2 | 4 |

**Note: mass per year approximations represent the amount of mass passing each site. Summations of loading at each site do not represent the cummulative flux per year for the stream. Rather, the total mass leaving a stream is best estimated from the most downstream sampling location.**

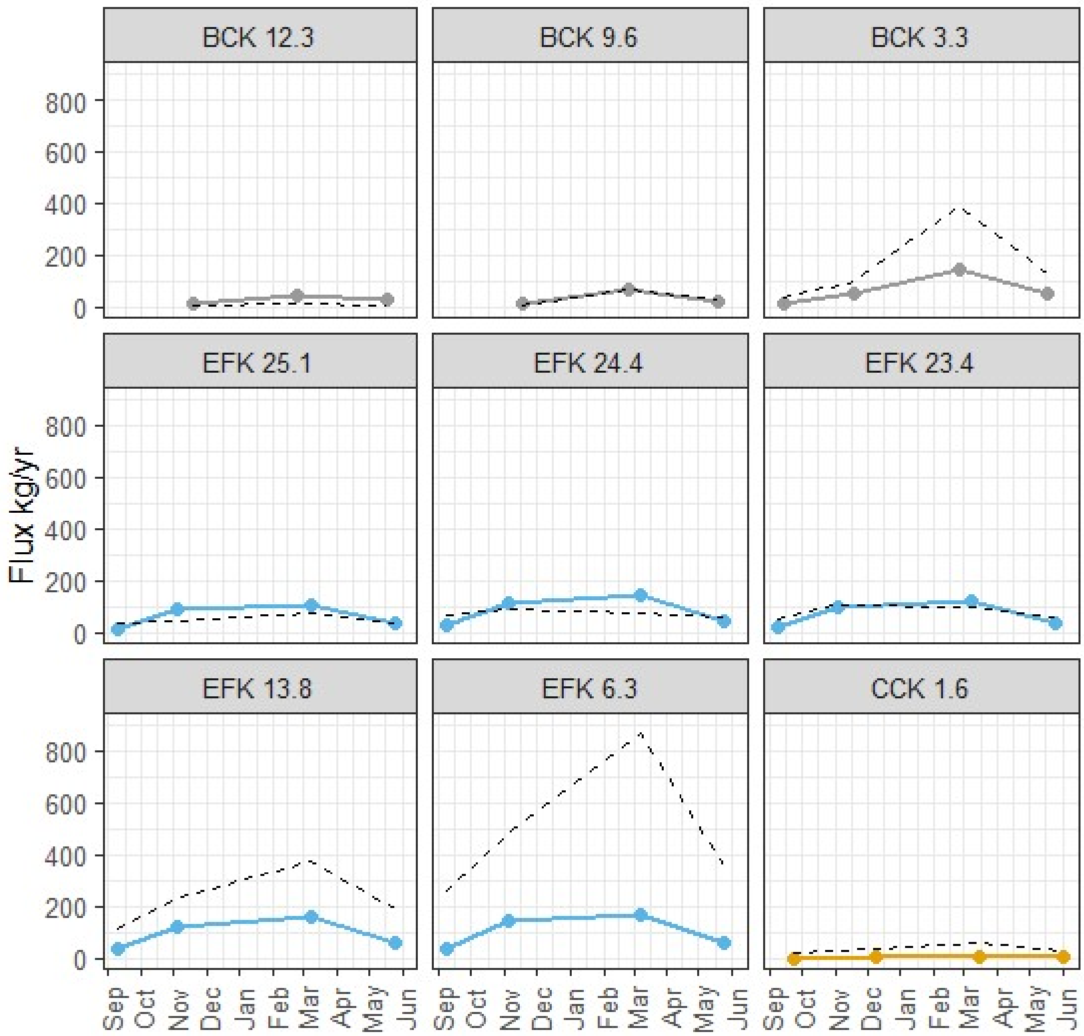


**Figure 9.2.10: Uranium flux for each station in g/yr. The dashed black line indicates the flux allowed based on the EPA drinking water MCL for uranium when using flow measured at time of sampling (i.e., MCL concentration multiplied by measured flow).**

Specific discussion on analytical results for each stream sampled is provided in the following sections of this project report.

**Bear Creek (BCK)**

Bear Creek has shown to have an ionic composition consisting primarily of calcium carbonate. Sodium and chloride are also present in smaller amounts. Nitrates are found in upper reaches of the stream at BCK 12.3 but dilute to very low concentrations downstream. An overall dilution of ions occurred from upstream to downstream during all times of the year (see Figures 9.2.6 and 9.2.7 above).

Bear Creek has very high concentrations of uranium, specifically in the upper sections of the stream. BCK 12.3 yielded uranium concentrations of 220 µg/L and BCK 9.6 yielded concentrations over 50 µg/L. While the stream is not used directly for drinking water, these concentrations are well over the EPA's 30 µg/L drinking water MCL which can be used as a comparison (Figure 9.2.11).

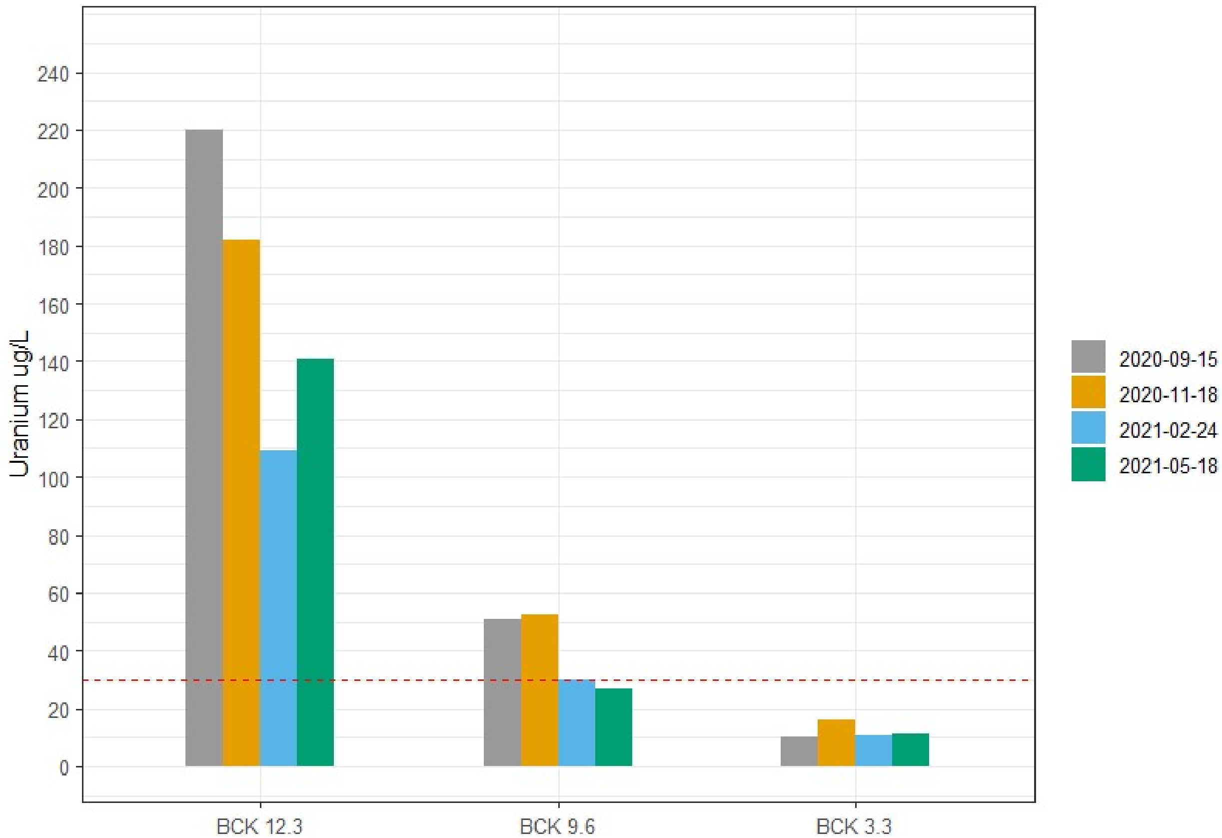


**Figure 9.2.11: Uranium concentrations for each sampling event at each station on Bear Creek. The dashed red line indicates the EPA drinking water MCL for uranium. Uranium concentrations decrease from upstream to downstream in all times of the year.**

While concentrations of uranium are higher in upstream sections, the overall stream discharge is lower. With increased flow downstream, more uranium mass is able to be passed through the system, yet remain under MCLs. It is approximated that Bear Creek may have 27 kg, 33 kg, and 64 kg of uranium pass by stations BCK 12.3, BCK 9.6, and BCK 3.3 each year, respectively. With an increase in flow in these lower stretches, the mass loading of uranium metal is much higher.

Mercury was also analyzed on Bear Creek and yielded low concentrations, well below the TN criteria of 0.05 µg/L for water and organisms (Figure 9.2.12). With these low concentrations, mercury mass loading was very low at each station. It is approximated that 1 g, 5 g, and 16 g of mercury pass by stations BCK 12.3, BCK 9.6, and BCK 3.3 each year, respectively. As these results only represent four sampling points, more data would be needed to provide a better understanding of mercury in all flow conditions, including storm events.

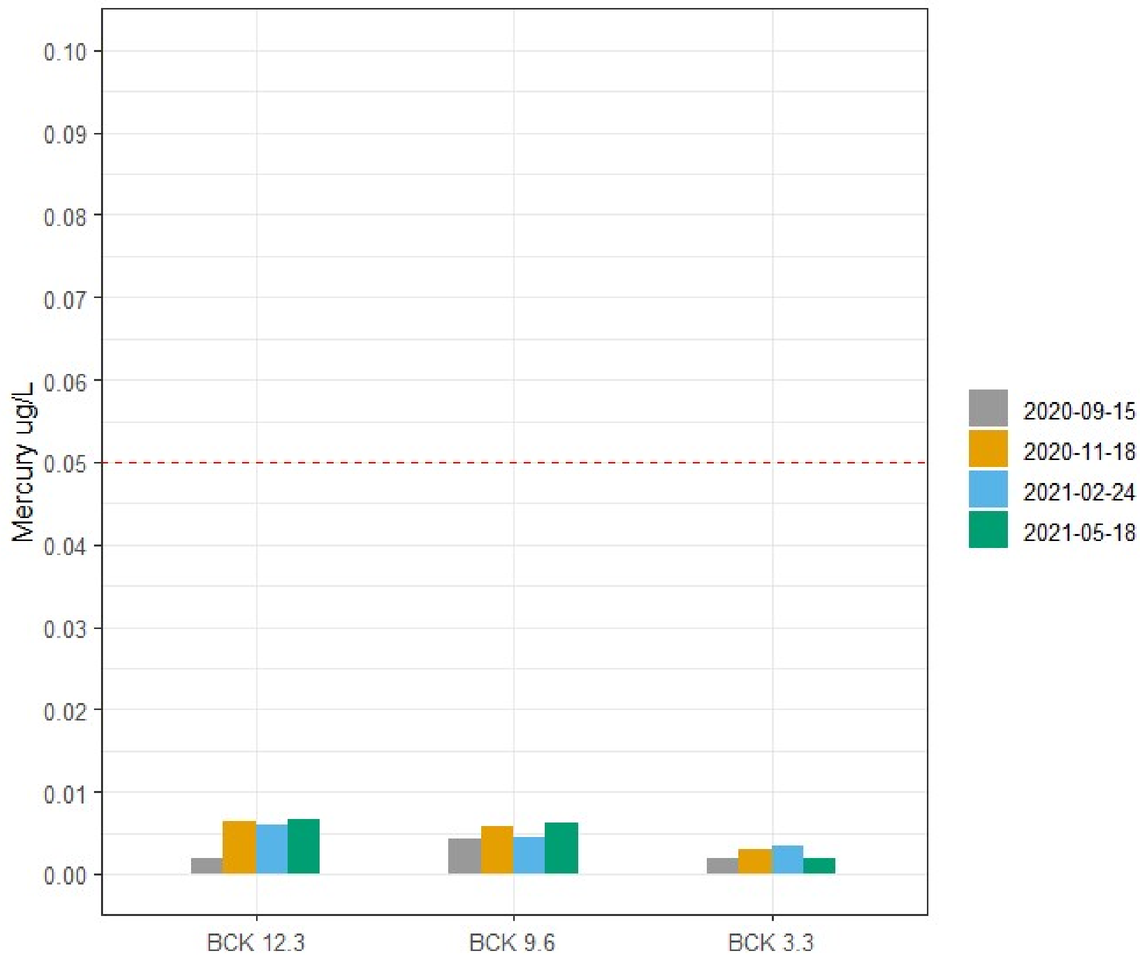


**Figure 9.2.12: Mercury concentrations for each sampling event at each station on Bear Creek. The dashed red line indicates the TN criterion of 0.05 µg/L for water and organisms.**

### East Fork Poplar Creek (EFK)

East Fork Poplar Creek was shown to have an ionic composition consisting primarily of calcium carbonate. Sodium and chloride were also present in smaller amounts. Magnesium and sulfates were also present at all stations. Overall, the ionic composition remained relatively the same throughout much of the year at all stations. (see Figures 9.2.4 and 9.2.5 above). Sodium and chloride appeared to decrease at EFK 13.8 but returned at downstream

EFK 6.3. This may be due to groundwater and surface water interactions where dilution may play a role from added groundwater.

East Fork Poplar Creek near Y-12 has concentrations of uranium well over the EPA's 30 µg/L drinking water MCL. While the stream is not used directly for drinking water, the MCL can be used as a comparison. Samples taken in November 2020 and March 2021 yielded the highest uranium concentrations, with values well over 30 µg/L at EFK 25.1, EFK 24.4, and EFK 23.4. All samples taken at all stations in September 2020 yielded results below the EPA drinking water MCL (Figure 9.2.13).

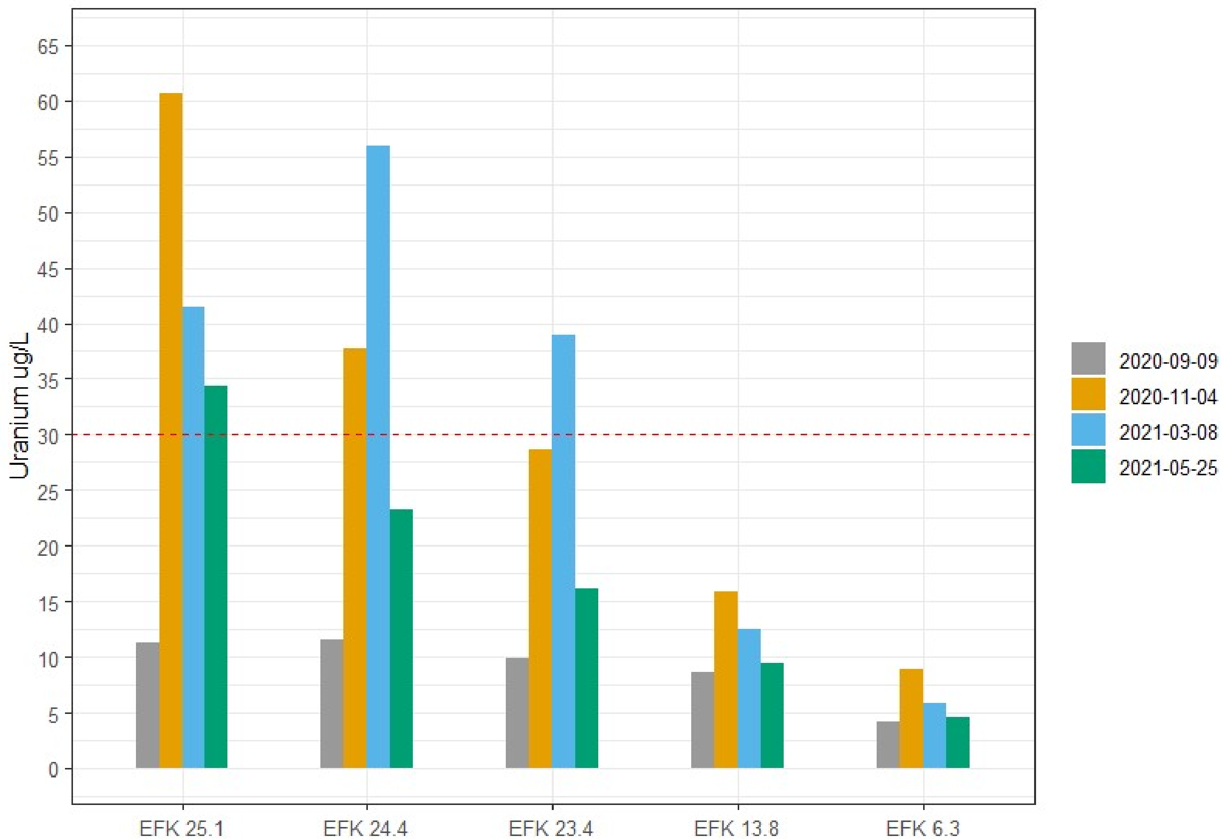


**Figure 9.2.13: Uranium concentrations on East Fork Poplar Creek. Red dashed line represents EPA drinking water MCL of 30 µg/L.**

Flow in EFPC increases downstream. While uranium metal concentrations may not be as high in the lower sections of the stream, the added flow allows for increased uranium mass loading. It is approximated that EFK 6.3 may have nearly 100 kg of uranium pass by each year based on the few samples and flow measurements taken. Earlier sections of the river such as EFK 25.1 had higher uranium concentrations but lower flow, yielding an approximated 60.8 kg of uranium passing by the station each year.

Mercury was also analyzed on EFPC and yielded concentrations well above the TN criterion for water and organisms of 0.05 µg/L (Figure 9.2.14). Upstream sections of EFPC yielded concentrations nearing 1.1 µg/L, or nearly 21 times the TN criterion. When accounting for flow at each site, it is approximated that nearly 1 kilogram of mercury passes by EFK 25.1 each year. This value decreases downstream to nearly 0.5 kg/year at EFK 6.3. While flow is increasing downstream, the mercury is either diluted or is sorbed to stream sediment.

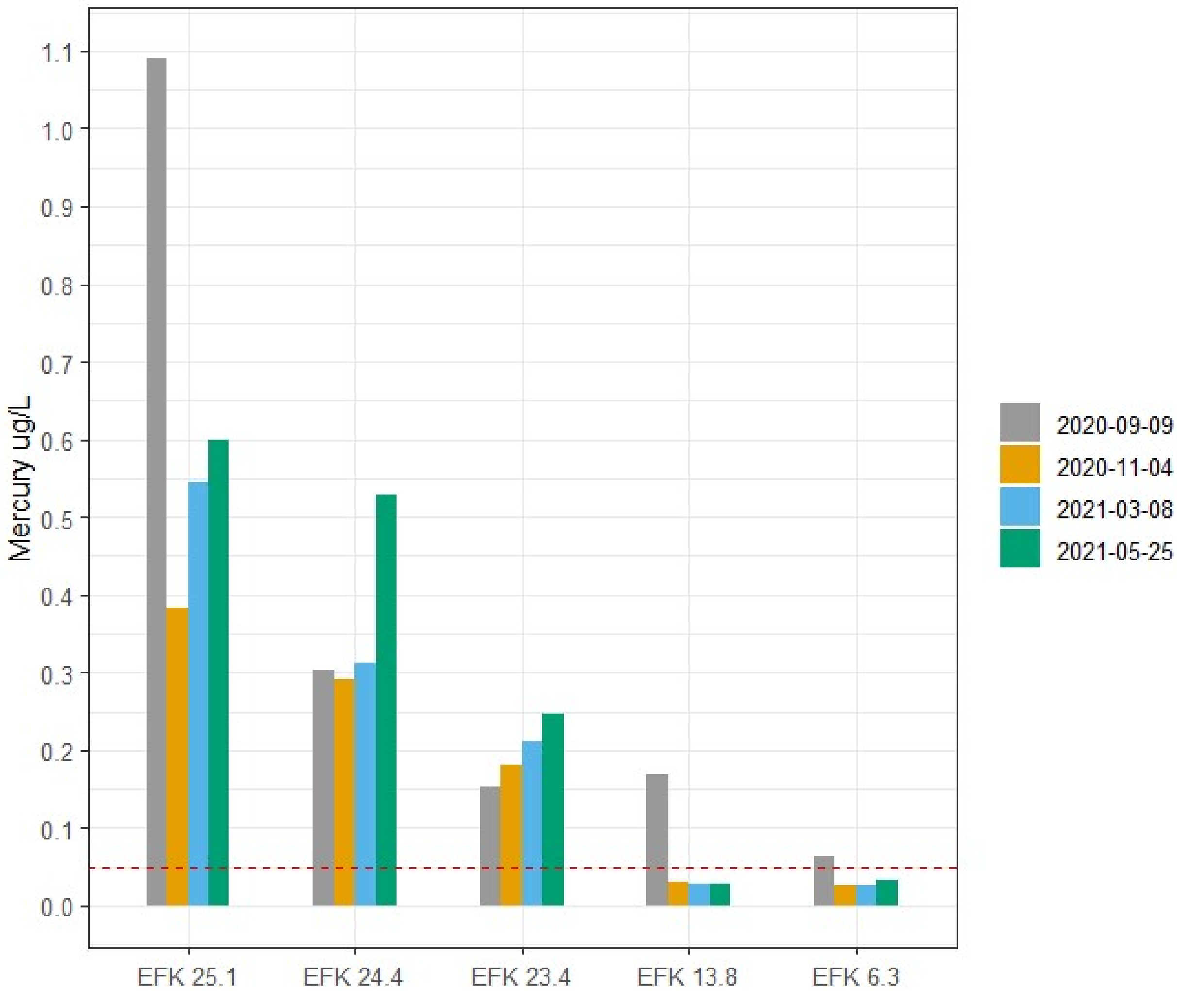


**Figure 9.2.14: Mercury concentrations on East Fork Poplar Creek. Red dashed line represents TN criterion for water and organisms of 0.05 µg/L.**

**Clear Creek (CCK)**

Clear Creek yielded low concentrations and even some non-detects for all samples measured. It provides a good background example to those streams on the ORR. Approximations of mercury and uranium loading were very low based on the overall flow of the stream. It is approximated that 1 gram of mercury and 239 grams of uranium may pass by this site ultimately loading the Clinch River each year. This is very small in comparison to the approximated 1 kilogram of mercury that passes by EFK 25.1 and the 100 kilograms of uranium that may potentially flow through the lower sections of EFPC each year.

**Clinch River (CRK)**

All of the Clinch River sample results were well below TN and EPA MCLs. Radionuclides and mercury were sampled at these locations and all resulted in relatively low activities and concentrations. CRK 32 yielded slightly higher strontium-90 values of 1.9 pCi/L. Yet, these values are well below the MCL of 8 pCi/L. Historically, nearby upstream location CRK 33.5 (mouth of White Oak Creek) had very high concentrations upwards of 50 pCi/L. This CRK 33.5 location was not sampled as part of this project this year. The slightly elevated strontium-90 values at CRK 32 are likely due to the input of strontium into the Clinch River from White Oak Creek. However, dilution of the Clinch River has brought the values below the 8 pCi/L MCL at CRK 32.

### 9.2.8 Conclusions

Several streams including BC, CC, and EFPC were sampled quarterly to focus on mercury and uranium loading. The Clinch River was also co-sampled quarterly with DOE. Bear Creek yielded high uranium concentrations at upstream locations at concentrations upwards of 220 µg/L. Concentrations of uranium decrease downstream from Y-12. Uranium loading shows an increase of uranium loading the creek in respect to distance from Y-12. While the loading may increase, the concentrations are lower at downstream locations. Mercury concentrations were low on Bear Creek being below TN criteria for organisms and water. East Fork Poplar Creek was high in both uranium and mercury concentrations in upstream locations near Y-12. Uranium concentrations decrease downstream of Y-12, yet the loading increases as the flow increases. A rough approximation based on limited samples and flow measurements indicates a potential of 100 kilograms of mercury passes by EFK 6.3 annually. While loading may be higher at EFK 6.3, the overall concentration of uranium is below EPA drinking water standards. Mercury on EFPC has higher loading of nearly a kilogram near Y-12 and decreases with distance from Y-12. Mercury may be diluted or sorbed to stream sediment and banks. Even though concentrations of mercury and uranium may be low in the downstream reaches of Bear Creek and East Fork Poplar Creek, it is important to monitor mass loading, via flux, in the streams because both mercury and uranium can bioaccumulate. Clear Creek, a background stream, showed only small concentrations or non-detections of contaminants. For perspective, this background stream loads potentially 1 gram of mercury to the Clinch River annually while EFPC site EFK 25.1 may potentially have 1 kg of mercury move by the site annually. The Clinch River was below all criteria for constituents sampled.

### 9.2.9 Recommendations

High mercury and uranium concentrations were found at EFPC and high uranium concentrations were found at BC. Until all areas of extensive anthropogenic-point and non-point source contamination on the ORR are fully remediated, the potential exists for pollution to contaminate surface waters on the ORR as well as downstream offsite aquatic systems. Accordingly, it is prudent for this project to continue assessing ORR exit pathway stream and Clinch River surface water conditions. In addition, it is recommended that flow measurements continue to be taken in conjunction with surface water sampling to assess the loading of contaminants from the ORR into the Clinch River, a major resource for many Tennessee citizens.

### 9.2.10 References

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## 9.3 WHITE OAK CREEK RADIONUCLIDES

### 9.3.1 Background

To help monitor potential ORR contamination, an ambient surface water sampling project has been implemented each year since 1993. This monitoring project began by investigating the water quality of the Clinch River at five locations near the ORR. The sampling locations for this project have been modified throughout the years, sometimes adding or discontinuing sampling at particular locations. At Clinch River kilometer (CRK) 32, TDEC DoR-OR staff co-sampled surface water with ORNL environmental staff on a quarterly basis during 2021 FY.

High strontium-90 (Sr-90) concentrations were found at site CRK 33.5 which is the White Oak Creek (WOC) and Clinch River confluence. Sr-90 concentrations were found to be nearly seven times the acceptable limit for the EPA drinking water limit of 8 pCi/L.

The average flow rate at the WOC dam, calculated from records provided by DOE, is 24,460 L/min with a median value of 14,325 L/min. As recent flow data was not available at this site, these values were calculated from 3,571 measurements conducted from 1993 to 2017.

Sr-90 was sampled at site CRK 33.5 on the Clinch River. The average concentration of Sr-90 over three sampling events was 36.7 pCi/L which is well above the EPA recommended 8 pCi/L limit for drinking water. Assuming the median flow value from sampling is representative of WOC near the Clinch River confluence and assuming that the average concentration of Sr-90 is representative of WOC, it is estimated that over 2.82E-05 grams per year (g/yr) of Sr-90 is added to the Clinch River from WOC.

The purpose of this project is to continue monitoring Sr-90 and other radiological contaminant inputs to WOC while loading of these contaminants to the Clinch River remains high.

### 9.3.2 Problem Statements

This project supplements DOE's study of the Clinch River to better understand the possibility of human beings being affected by migrating ORR radioactivity. Based on 2017 US census data, it is estimated that nearly 1.2 million people live in the counties surrounding the ORR (DOE, 2017). A large portion of these people have the potential of being influenced by streams that drain the ORR. All the exit-pathway streams on the ORR eventually flow into the Clinch River. In turn, the Clinch River ultimately flows into the Tennessee River. Twelve water supplies are located on these rivers within 170 river miles downstream of WOC (DOE, 1992). The Clinch River alone provides drinking water as well as water for industrial use to many municipalities near and downstream of the ORR. These include Anderson County, Knox County, Roane County, the City of Clinton, the City of Kingston, the City of Norris, and the City of Oak Ridge. The Clinch River surface waters are also used for facilities at the Y-12 National Security Complex (Y-12), the Oak Ridge National Laboratory (ORNL), and the East Tennessee Technology Park (ETTP). Thus, it is important to monitor this exit pathway stream to better understand the ORR's impact on the region's widely used water resources.

These ORR exit-pathway streams and the Clinch River are subject to legacy and current contaminant releases from activities at ETTP, ORNL, and Y-12. These releases can be detrimental to the environment and to human health. Identified concerns include but are not limited to the following:

- The Clinch River received approximately 665 curies of cesium-137 (Cs-137) from White

Oak Creek between 1954 and 1959. (DOE, 1992)

- Elevated levels of radioactive strontium-90 have been seen in WOC after a 2015 ruptured pipe mobilized the contaminant at the Process Waste Treatment Complex (DOE, 2018)

By monitoring WOC, TDEC DoR-OR can better assess what locations on the ORR are contributing to surface water pollution and provide insight to help protect human health and the environment, especially for the important resource of the Clinch River.

### 9.3.3 Goals

The goal of this WOC Radionuclides monitoring project is to evaluate the impacts of DOE ORR contamination to WOC and the Clinch River (see Fig. 9.3.1). This project ultimately seeks to understand WOCs contribution of contaminants to the Clinch River. An assessment of WOCs impacts to the Clinch River is performed by comparing results to EPA maximum contaminant levels (EPA, 2009). Overall, this project helps to define areas of concern on the ORR that may be significantly impacting the surface water resources of Tennessee.

To accomplish this goal, several objectives need to be completed. These objectives include:

1. Collect quarterly surface water samples at the selected WOC and Clinch River sites
    a. Samples will be collected and analyzed for strontium-89/90
2. During sampling, physical waters parameters (e.g., conductivity, dissolved oxygen, pH and temperature) will be measured

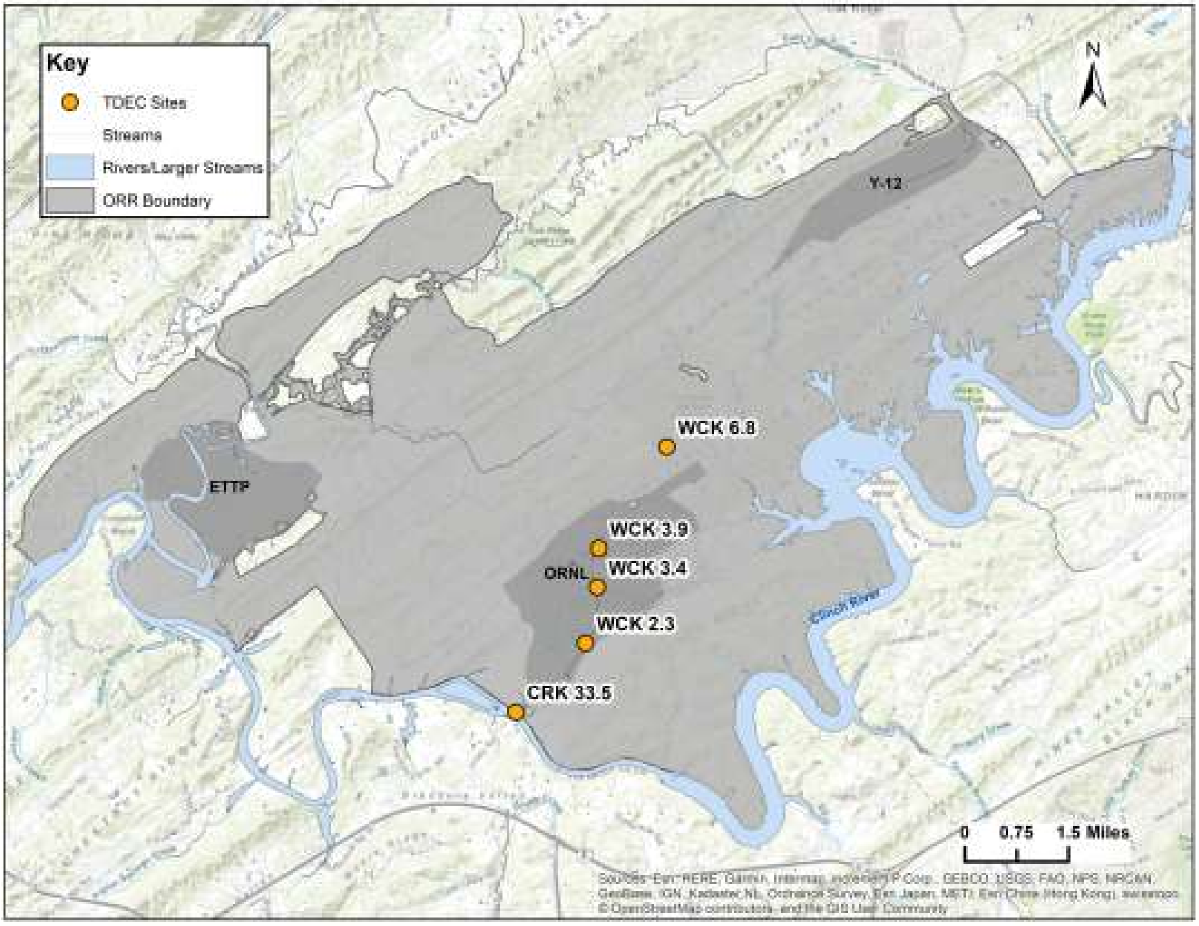


**Figure 9.3.1: Map showing TDEC DoR-OR Sampling Sites**

## 9.3.4 Scope

The scope of this project was to characterize stream conditions and assess contaminant flux through sampling the surface waters of WOC and the Clinch River.

## 9.3.5 Methods, Materials, Metrics

Surface water samples were collected quarterly at four sites on WOC and one on the Clinch River. Samples were collected and analyzed for strontium-89/90 at each site (see Table 9.3.1). Quality assurance/quality control (QA/QC) samples were taken every 10th sample of a given analyte. If less than ten samples were collected for a given analyte, at least one QA/QC sample was collected (see Table 9.3.1). To ensure reproducible results, sample collection utilized the *TDEC, DWR, Quality System SOPs for Chemical and Bacteriological Sampling of Surface Water,* DWR-WQP-P-01- QSSOP-Chem-Bact-082918.

**Table 9.3.1: Site locations, descriptions, and list of proposed analytes**

| DoR-OR Site | Site Latitude | Site Longitude | Analyte |
|---|---|---|---|
| WCK 6.8 | 35.94151 | -84.30161 | Sr-89/90 |
| WCK 3.9 | 35.92435 | -84.31579 | Sr-89/90 |
| WCK 3.4 | 35.91778 | -84.31612 | Sr-89/90 |
| WCK 2.3 | 35.90834 | -84.31856 | Sr-89/90 |
| CRK 33.5 | 35.896653 | -84.333161 | Sr-89/90 |

At each site, physical water parameters were collected during the time of sampling. Physical parameters were measured using a multiple parameter water quality meter. Parameters of conductivity (μS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) were recorded along with time of measurement. The water quality meter was used according to manufacture specifications.

Upon receiving sampling results, data was stored in a database maintained in the TDEC DOR-OR office. Data was compared to an EPA defined MCL to determine if there were any exceedances (EPA, 2009). Any exceedances invoked further investigation. See the table below for the comparison criteria (see Table 9.3.2).

**Table 9.3.2: Criteria for screening samples**

| Contaminant | Criterion | Reference |
|---|---|---|
| Sr-89/90 | 8 pCi/L* | EPA 2009 |

*EPA has established a Maximum Contaminant Level (MCL) of 4 millirems per year for beta particle and photon radioactivity from manmade radionuclides in drinking water. The value shown is the average concentration assumed to yield 4 millirems per year. If other radionuclides that emit beta particles and photon radioactivity are present in addition to this contaminant, the sum of the annual dose from all the radionuclides cannot exceed 4 millirems per year.

### 9.3.6 Deviations from the Plan

Three quarters of sample data is presented here.  it should be noted that it was not always possible to collect all samples on the same day in a quarter, though attempt was made to pair collections as closely as possible. During this FY POP, on 2 occasions, schedule adjustments were made to accommodate additional boat or HP / health and safety required support.

### 9.3.7 Results and Analysis

Results are as follows:

**Table 9.3.3 Sample Results: (pCi/L)**

| | 2020 Q3 | 2021 Q1 | 2021 Q2 | 2021 Q2 | 2021 Q2 |
|---|---|---|---|---|---|
| Location | 8/25/2020 | 3/30/2021 | 4/7/2021 | 6/9/2021 | 6/15/2021 |
| WCK 6.8 | 1.9 | 0.91 | | 1.04 | |
| WCK 3.9 | 47 | 31 | | 27 | |
| WCK 3.4 | 50.2 | 4.83 | | 72.5 | |
| WCK 2.3 | 55.4 | 29.2 | | 86 | |
| CRK 33.5 | 32 | | 16.9 | | 41 |
| Max result | 55.4 | 31 | 16.9 | 86 | 41 |
| Average | 37.3 | 16.49 | 16.9 | 46.64 | 41 |

Note: Sample results units are expressed in in pCi/L. Negative numbers were not reported (Table 9.3.3).

### 9.3.8 Conclusions

In general, this sampling continued to confirm prior observations that the Strontium-89/90 contaminants identified in this watershed continue to enter White Oak Creek as it flows through ORNL. WCK 6.8, the background location that is sampled above ORNL, returned much lower results than the values provided by samples collected within the creek and at the confluence with the Clinch River. It also provided values associated with the discharges that can be identified entering the Clinch River from this tributary.

The TDEC DoR-OR samples collected at the CRK 33.5 sampling location (from the White Oak Creek Embayment into Clinch River), during 8/25/2020, 4/7/2021 and 6/15/2021, and analyzed for Strontium 89/90, all exceeded the EPA MCL's for drinking water, that was used as a reference comparison for this work.

### 9.3.9 Recommendations

TDEC DoR-OR recommends continuing monitoring White Oak Creek strontium-89,90 levels.

### 9.3.10 References

DOE. (1992). Federal Facility Agreement (FFA). Appendices for the Oak Ridge Reservation. Oak Ridge Site Description – UCOR, Appendix B (2017 revision). DOE/OR-1014. U. S. Department of Energy. Retrieved from http://www.ucor.com/docs/ffa/appendices/AppendixB.pdf

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# 10.0 WATERSHED ASSESSMENTS (HOLISTIC) MONITORING

## 10.1 BEAR CREEK VALLEY ASSESSMENT

### 10.1.1 Background

This project involves an intensive evaluation of the environmental health of the Bear Creek Watershed. It includes field sampling of surface water, sediment, soils, vegetation, toxicity, fish, benthic macroinvertebrates, and other biota (bird eggs, insects, spiders, and crayfish) at the sites listed in Table 10.1.1. A background stream, Mill Branch, was be sampled at kilometer 1.6 (MBK 1.6). The surface water sampling component of the Bear Creek Assessment Project (BCAP) was conducted in 2019. Sampling of the other environmental media was completed during the 2020-2021 fiscal year.

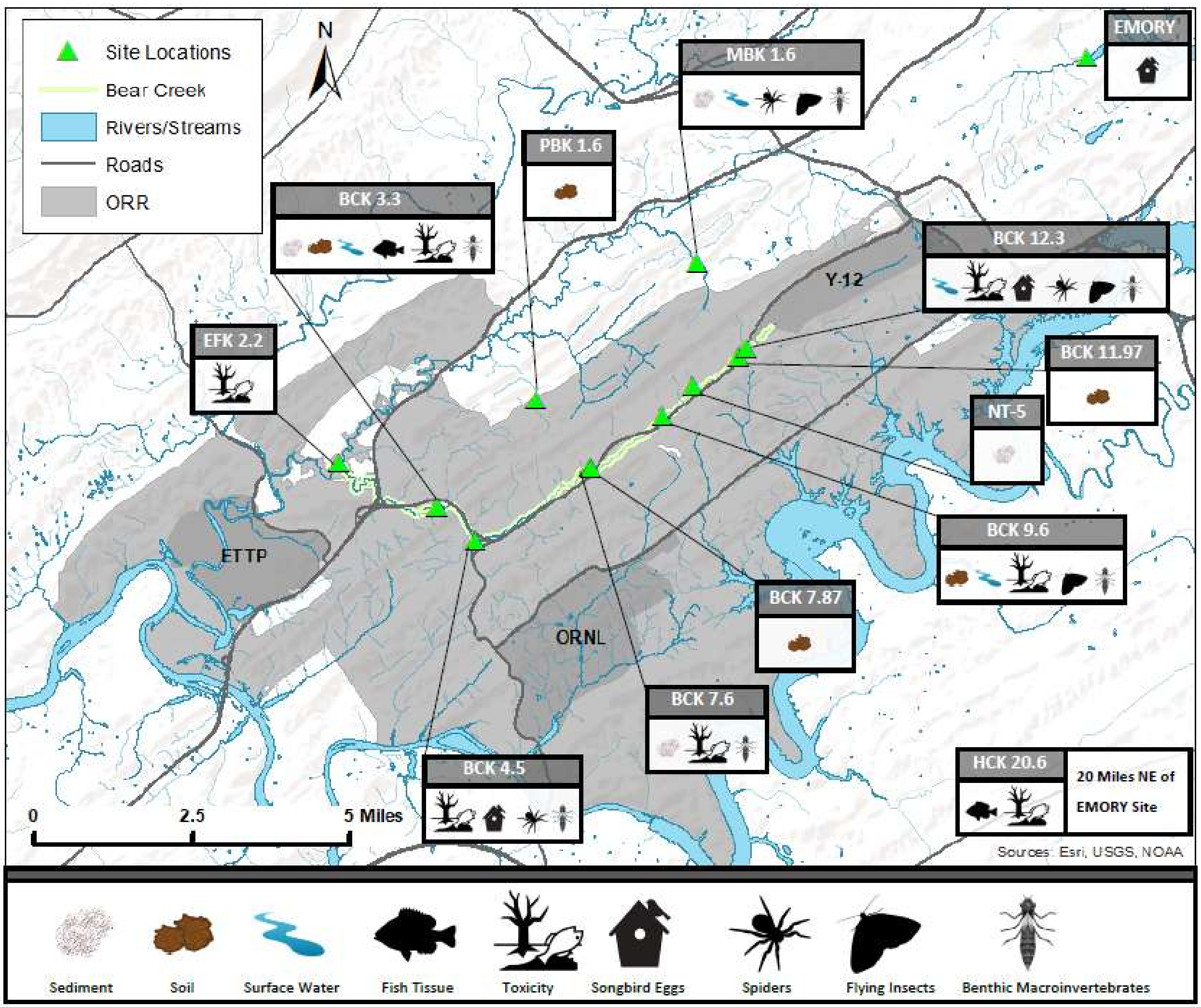


**Figure 10.1.1: Map of the BCAP Sampling locations**

**Table 10.1.1: BCAP Sampling Sites**

| Site Description | Name | Latitude | Longitude |
|---|---|---|---|
| Bear Creek kilometer 3.3 | BCK 3.3 | 35.94354 | -84.34911 |
| Bear Creek kilometer 4.5 | BCK 4.5 | 35.93731 | -84.34013 |
| Bear Creek kilometer 7.6 | BCK 7.6 | 35.95096 | -84.31395 |
| Bear Creek kilometer 7.87 | BCK 7.87 | 35.950622 | -84.313795 |
| Bear Creek kilometer 9.6 | BCK 9.6 | 35.96032 | -84.29741 |
| North Tributary 5 of Bear Creek | NT-5 | 35.96603 | -84.29024 |
| Bear Creek kilometer 11.97 | BCK 11.97 | 35.971489 | -84.279735 |
| Bear Creek kilometer 12.3 | BCK 12.3 | 35.973 | -84.27814 |
| East Fork Poplar Creek kilometer 2.2 | EFK 2.2 | 35.95169 | -84.3716 |
| Emory Background Site | EMORY | 36.02698 | -84.19983 |
| Hinds Creek kilometer 20.6 | HCK 20.6 | 36.15797 | -83.99944 |
| Mill Branch kilometer 1.6 | MBK 1.6 | 35.98886 | -84.28935 |
| Pinhook Branch kilometer 1.6 | PBK 1.6 | 35.963495 | -84.326492 |

The BCK 12.3 site is representative of the headwater's region of the stream. NT-5 is a tributary to Bear Creek that discharges from the low-level hazardous and mixed-waste landfill, the Environmental Management Waste Management Facility (EMWMF). BCK 9.6 is located at the downstream end of Bear Creek Remediation Zone 3. Similarly, BCK 7.6 is located at the downstream end of Bear Creek Valley Zone 2. BCK 4.5 is located at the point where Bear Creek leaves the Y-12 restricted area at the downstream extent of Zone 1. The offsite region of Bear Creek is represented by BCK 3.3; this section of the stream from BCK 4.5 downstream to Poplar Creek is not restricted from public access by the Department of Energy (DOE).

### 10.1.2 Problem Statements

DOE has not conducted a comprehensive assessment of BCK 3.3 or areas downstream on Bear Creek; this project is being conducted to assure the public that the areas of Bear Creek outside of the Y-12 restricted area are safe for recreation. Another purpose for this project is to provide a baseline of environmental data prior to the construction of the proposed EMDF landfill.

### 10.1.3 Goals

- Provide an intensive evaluation of Bear Creek in order to document a baseline of environmental parameters for future reference.

    - Time this data collection to precede the construction of the proposed EMDF landfill to support future assessments and comparisons.
- To assure the people of the State of Tennessee, that the sections of Bear Creek accessible to the public do not pose a health threat to those using the area for recreation.

### 10.1.4 Scope

The scope of this project was limited to the environmental assessment of Bear Creek through sampling and analysis of surface water, surface water toxicity, sediment, soil, benthic macroinvertebrate communities, fish tissue, vegetation, and other biota tissue (bird eggs, crayfish, adult insects, and spiders). The stream reach being assessed was from the mouth of Bear Creek at East Fork Poplar Creek km 2.2 (EFK 2.2) to BCK 12.3.

### 10.1.5 Methods, Materials, Metrics

**Sediment** sampling was conducted at four locations twice during the year; sampling locations are: NT-5, BCK 7.6, BCK 3.3, and MBK 1.6. Suspended sediment samples were collected by using fixed sediment collection devices (traps). Sediment traps are installed in a stream bed in a position where considerable flow through the body of the trap occurs. Suitable sites are limited in a stream and careful consideration must be given to selecting installation locations for the sediment traps. Sufficient flow and adequate depth must be sufficient to completely immerse the sediment traps.

Following a collection period of a minimum of four months, the collected sediment is emptied from a sediment trap and is transferred to a clean bucket where the sediment is allowed to settle for 24 to 48 hours. After the sediment is allowed to settle, the supernatant water is carefully drawn off the sample with a peristaltic pump. Sediment samples are spooned from the bucket into sample containers. Sediment samples were analyzed for gross alpha, gross beta, gamma radionuclides, strontium 89, 90 (Sr-89,90), isotopic uranium, semivolatiles, PCBs, pesticides, and metals (arsenic (As), barium (Ba), beryllium (Be), boron (B), cadmium (Cd), cesium (Cs), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), strontium (Sr), uranium (U), and zinc (Zn)). The sediment samples were sent to the Tennessee Department of Health Laboratory Services in Nashville (TDH-NEL) for analysis.

**Surface Water** samples were collected in May 2019 at BCK 12.3, 9.6, 3.3 and MBK 1.6. The samples were analyzed for metals and radiochemistry parameters.

**Toxicity** sampling was conducted in the fall of 2020 for each location in BCK 12.3, 9.6, 7.6, 4.5, 3.3, and EFK 2.2 (mouth of Bear Creek). HCK 20.6 was also sampled as a background site. Two to three gallons of stream water were collected at each of the sampling sites on Monday, Wednesday, and Friday for one week and then shipped to Pace Analytical Laboratory for testing. Testing included survival and reproduction for water fleas (*Ceriodaphnia dubia)* and survival and growth for fathead minnows (*Pimephales promelas*).

**Soil** sampling occurred once in the fall of 2020 at BCK 11.97, 9.6, 7.87, 3.3 and at PBK 1.6 (background location). Samples were collected by hand auger to a depth of six inches. Several samples were collected at each location and composited for the sample submitted for analysis. Samples were analyzed for gross alpha, gross beta, Sr-89,90, isotopic uranium, semivolatiles, PCBs, pesticides, and metals (As, Ba, Be, B, Cd, Cs, Cr, Cu, Pb, Hg, Ni, Se, Sr, U, and Zn).

**Fish** sampling took place once in the fall of 2020 at two locations: BCK 3.3, and a background stream, Hinds Creek (HCK 20.6). Fish were collected by Oak Ridge National Laboratory's (ORNL) Environmental Sciences Division (ESD) by electroshocking. Sunfish tissue was analyzed for gross alpha, gross beta, gamma radionuclides, isotopic uranium, and technetium-99. Analysis of the fish tissue was conducted by ALS Laboratory.

**Vegetation** sampling was conducted on June 1, 2021, at BCK 12.3, 9.6, 7.6, 4.5, and 3.3. Also, MBK 1.6 was sampled as a background site. Herbaceous terrestrial plant parts (soft leaves and shoots) living in the flood plain are harvested with hand tools in order to obtain the samples. Samples were sent to TDH-NEL to be analyzed for gross alpha, gross beta, Sr-89,90, isotopic uranium, and metals (As, Ba, Be, B, Cd, Cs, Cr, Cu, Pb, Hg, Ni, Se, Sr, U, and Zn).

**Benthic macroinvertebrates** were e sampled in the spring of 2021 at BCK 12.3, BCK 9.6, and BCK 3.3. Various population metrics will be determined from the sample compositions.

**Biota** sampling took place at BCK 12.3, 9.6, 7.6, 4.5, and 3.3 in the Bear Creek floodplain and from a background site. The sampling plan for these sites included collecting songbird eggs, spiders, and flying insects. Biota samples were analyzed for gross alpha, gross beta, gamma radionuclides, Sr-89/90, and Tc-99.

**Songbirds:** Songbird nest boxes were installed at five Bear Creek locations and four reference locations on the ORR. Songbird nest boxes were checked periodically to determine occupancy. Once a nest box was confirmed to have a bird occupant, the box was checked twice per week to collect the 1st-laid and 2nd-laid eggs for analysis. Songbird breeding season runs from March to August and may have two broods per season.

**Spiders:** Spiders, mainly Wolf and Fishing spiders, were sampled by TDEC DoR-OR staff at the Bear Creek sites and at Mill Branch MBK 1.6. Sampling activities took place on June 16, 2021. During night hours, flashlights held at eye level located the reflective spider eyes near the stream shoreline or adjacent floodplain area (Northam et al., 2011). Then, the spider was retrieved using 12-inch forceps. During collection, spider specimens were placed into plastic cups with lids, to prevent escape, until ≥ 5 grams of biomass per sample was achieved.

**Adult Insects:** Insects were sampled by DoR-OR staff at BCK 12.3, BCK 9.6 and at Mill Branch MBK 1.6. ORR insects were collected on June 16, 2021, with a black light collector device ("Larry's Lighthouse"-BioQuip Products, Inc.). Nocturnal insects are attracted to the black light which provides maximum insect response from as far away as 500 meters from the light source. The Larry's Lighthouse device has a white mesh globe, no-see-um material, with the black light inside that attracts the insects after dark. After numerous insects had landed on the globe, they were hand collected using an aspirator vacuum tool which removed the bugs from the white mesh globe and were then secured in replaceable sample vials.

**Sampling and Handling at the TDEC DoR-OR Laboratory (all biota samples):**

In the TDEC DoR-OR laboratory, all biota samples were weighed and recorded in the laboratory sample log; (each sample had 5 grams of biomass). Measurements of egg width, breadth, and eggshell thickness were recorded with a digital micrometer in millimeters. Some egg samples were boiled to facilitate separation of shell, yolk, and albumen. All biota samples were placed into special 2-oz QEC (Quality Environmental Containers, Beaver, WI) Level 2 pre-cleaned glass jars with labels and screw-top plastic lids. These sample jars were stored at -18ºC in the TDEC DoR-OR laboratory freezer until shipment to PACE Analytical Services, LLC for analysis.

### 10.1.6 Deviations from the Plan

- Per- and polyfluoroalkyl substances (PFAS) testing for surface water, sediment, and soil was added to the plan in the spring of 2021.
- The sediment samples collected in February 2021 were analyzed for metals and radiological parameters only; the samples collected in June 2021 were analyzed for organics. Metals analysis was not conducted at BCK 7.6; the sample size was insufficient.
- Soil sampling was conducted by an environmental consulting firm, Civil & Environmental Consultants (CEC), using Incremental Sampling Methodology (ISM). TDEC DoR-OR staff helped conduct the sampling.
- Fish samples were obtained from BCK 3.3 and HCK 20.6 (background) only. The

samples consisted of various sunfish species and the sample was only sufficient to perform limited radiological analyses. A fish sample could not be obtained from EFK 2.2. Analysis of the fish tissue was conducted by the TDH-NEL and Eberline laboratories rather than ALS.

- Crayfish samples could not be obtained as there were not enough available to support required mass for analysis.
- Spider and adult insect samples were collected at BCK 12.3, 9.6 and at the background site, MBK 1.6. Samples were only sufficient for radiological analyses.
- Songbird egg samples were available only at BCK 12.3, 4.5 and at the EMORY background site. Samples were only submitted for radiological analyses.
- Vegetation samples were collected and submitted to the TDH-NEL for radiological analysis. Unfortunately, a laboratory device malfunctioned, and the samples were destroyed. There was not enough time to re-sample before the end of the fiscal year.

### 10.1.7 Results and Analysis

**Sediment**

Trapped sediment results were compared with the Consensus Based Sediment Quality Guidelines (CBSQGs) Probable Effects Concentrations (PECs) for some metals. There are CBSQGs for a limited number of metals. Metals data were not available for the BCK 7.6 site; the sample size was insufficient for metals analysis. The PECs are CBSQGs that were established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (MacDonald et al. 2000). Adverse effects, in this case, refer to the effects to benthic macroinvertebrate species only (WDNR 2003). The CBSQGs are considered protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases, in addition to the CBSQGs, other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue-residue guidelines should be used to assess direct toxicity and food chain effects. The threshold effects concentrations (TECs) are concentrations below which adverse effects are not expected to occur (MacDonald et al. 2000). In addition, sample results were compared with data from a background sediment trap sampling station, Mill Branch km 1.6 (MBK 1.6). Organics analysis results have yet to be received from the TDH-NEL.

**Arsenic (Sediment)**

Arsenic was not identified as an issue in Bear Creek sediments; all current data were non-detects.

**Barium (Sediment)**

Barium at the Bear Creek sediment sites was found to be about twice that of the Mill Branch background station (Figure 10.1.2). There is not a CBSQG for barium. Barium forms insoluble salts with carbonate and sulfate in the environment. As such, it is not mobile and poses little risk. It is found in low levels in most terrestrial soils, but hazardous waste sites may have higher levels. Most naturally occurring barium compounds are not a health risk due to their low solubility in water. Other barium compounds that are sometimes found at waste sites include barium acetate, barium chloride, barium hydroxide, barium nitrate, and barium sulfide; these compounds are more soluble in water (ATSDR 2007).

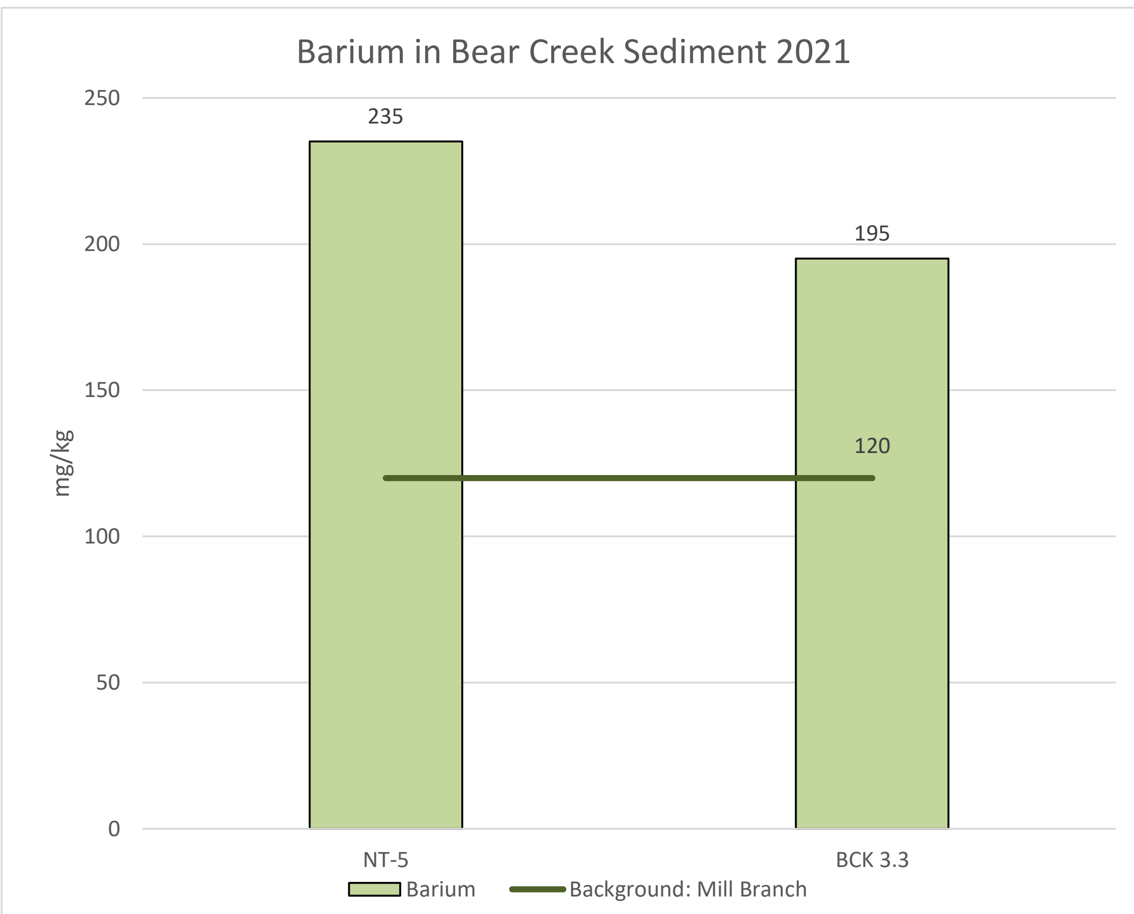


**Figure 10.1.2: Sediment Barium**

**Boron (Sediment)**

Boron values were higher than background (Figure 10.1.3). There is not a CBSQG for boron. Boron is the 51st most common element in the earth's crust. The average boron concentration of the entire earth's crust is 8 mg/kg where average soil concentrations are 26-33 mg/kg. Boron combines with oxygen in the environment to form borates. Borate minerals are mined, processed, and used for such purposes as: glass and ceramics, soaps, bleaches, fire retardants, and pesticides (ATSDR 2010). The isotope boron-10 is used as radiation shielding and for radioactivity control. Exposure to humans is primarily through ingestion of food and water, through pesticides or cosmetics containing boron. Adults consume on average about 1.0 to 1.28 mg boron each day (mainly from fruits and vegetables). Boron concentrations in natural soils can be as high as 300 mg/kg; the amounts found in Bear Creek, although higher than background, are not out of the ordinary and do not pose a health risk to humans or wildlife.

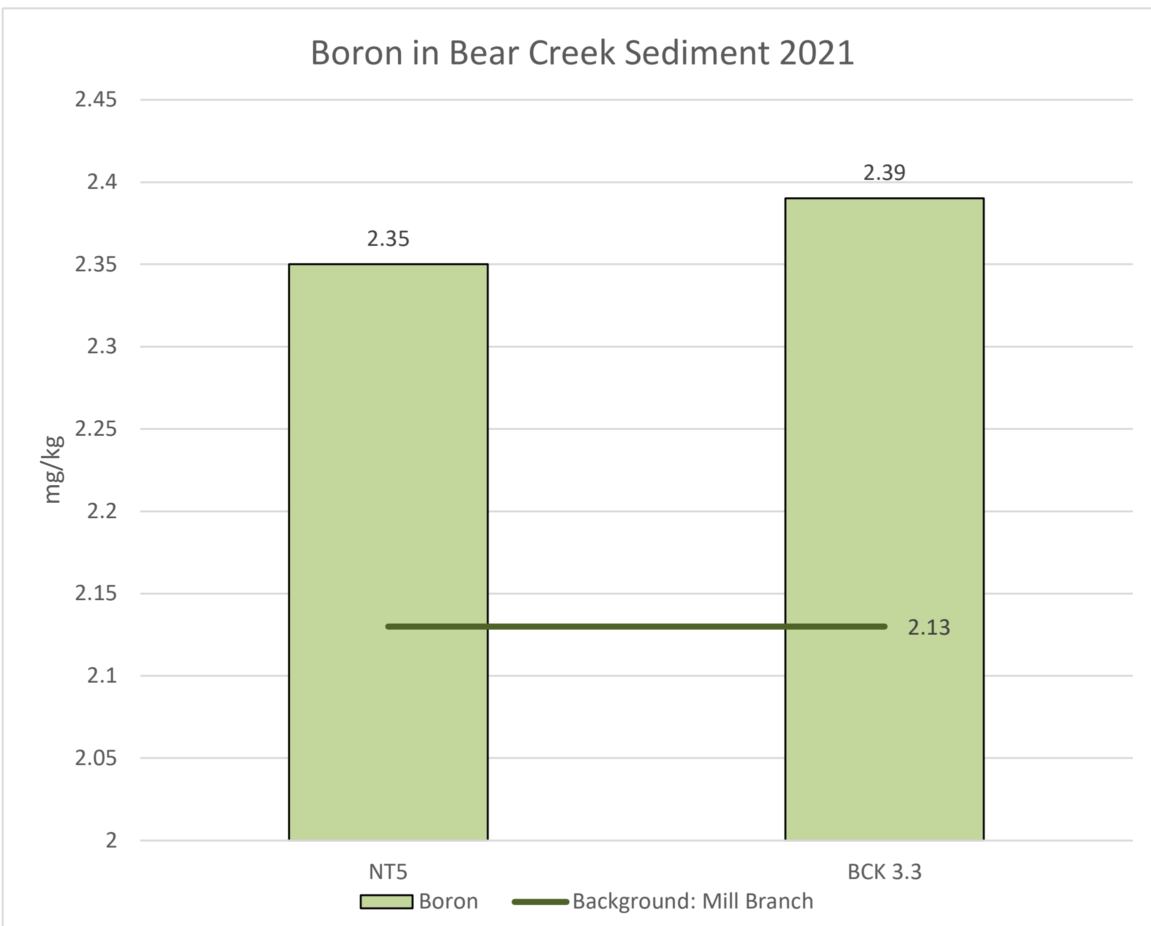


**Figure 10.1.3: Sediment Boron**

**Cadmium (Sediment)**

The cadmium level at BCK 3.3 was slightly elevated; the BCK 3.3 datum was higher than both the TEC and background, but lower than the PEC (Figure 10.1.4). The NT-5 cadmium value was similar to background, indicating the EMWMF was likely not the source of elevated cadmium in Bear Creek. Cadmium is found in the earth's crust, usually associated with zinc, lead, and copper ores and is extracted during the processing of these other metals. Cadmium is predominantly used for batteries, with other uses including pigments, coatings and platings, stabilizers for plastics, nonferrous alloys, and photovoltaic devices. Cadmium chloride and cadmium sulfate are soluble in water. Cadmium binds strongly to organic matter and can bioaccumulate in aquatic organisms and vegetation (ATSDR 2012 - Cadmium).

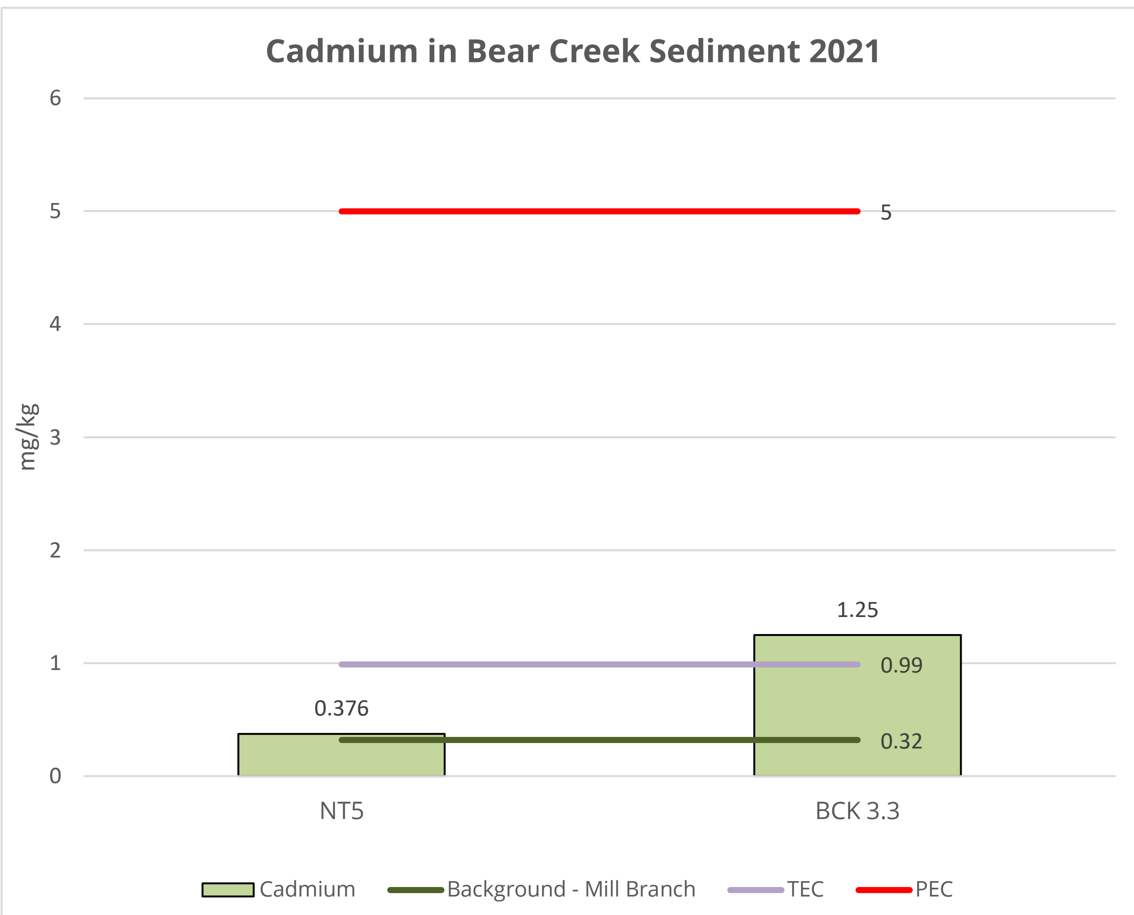


**Figure 10.1.4: Sediment Cadmium**

**Chromium (Sediment)**

Chromium was not an issue with Bear Creek sediments as data were much less than the CBSQGs and only slightly higher than background (Figure 10.1.5). Chromium (III) is necessary for normal human health. Chromium is naturally present in soil, rocks, plants, and animals. It is used to make alloys with steel which are more resistant to corrosion (stainless steel). It is also found in many in other materials, such as lumber, leather, cookware, and some artificial hip replacement components. Sources of chromium in the environment include industries involved in producing these products. The burning of oil, coal and natural gas can also introduce chromium to the atmosphere. Chromium does not stay in the atmosphere very long, as it settles on soil and surface water (ATSDR 2012 – Chromium).

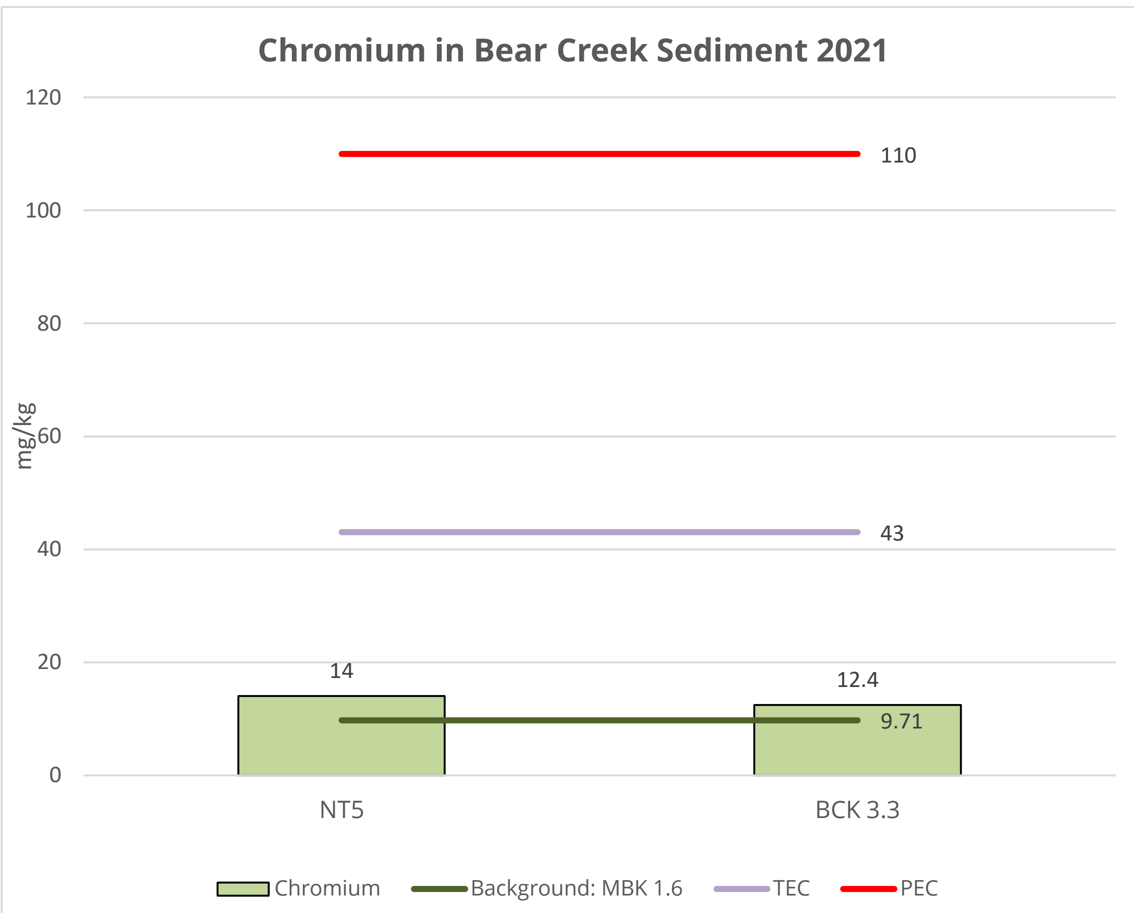


**Figure 10.1.5: Sediment Chromium**

## Copper (Sediment)

Copper values for Bear Creek sediments were not a concern; the values at NT-5 and BCK 3.3 were similar to background and much lower than the CBSQGs (Figure 10.1.6). Copper binds strongly to organic matter and minerals and does not travel very far after release in the environment. However, in streams, it can travel far when bound to sediment particles that are capable of being suspended in the current. Copper is stable and does not break down in the environment; it can accumulate in biota where it is found in soils and sediments.

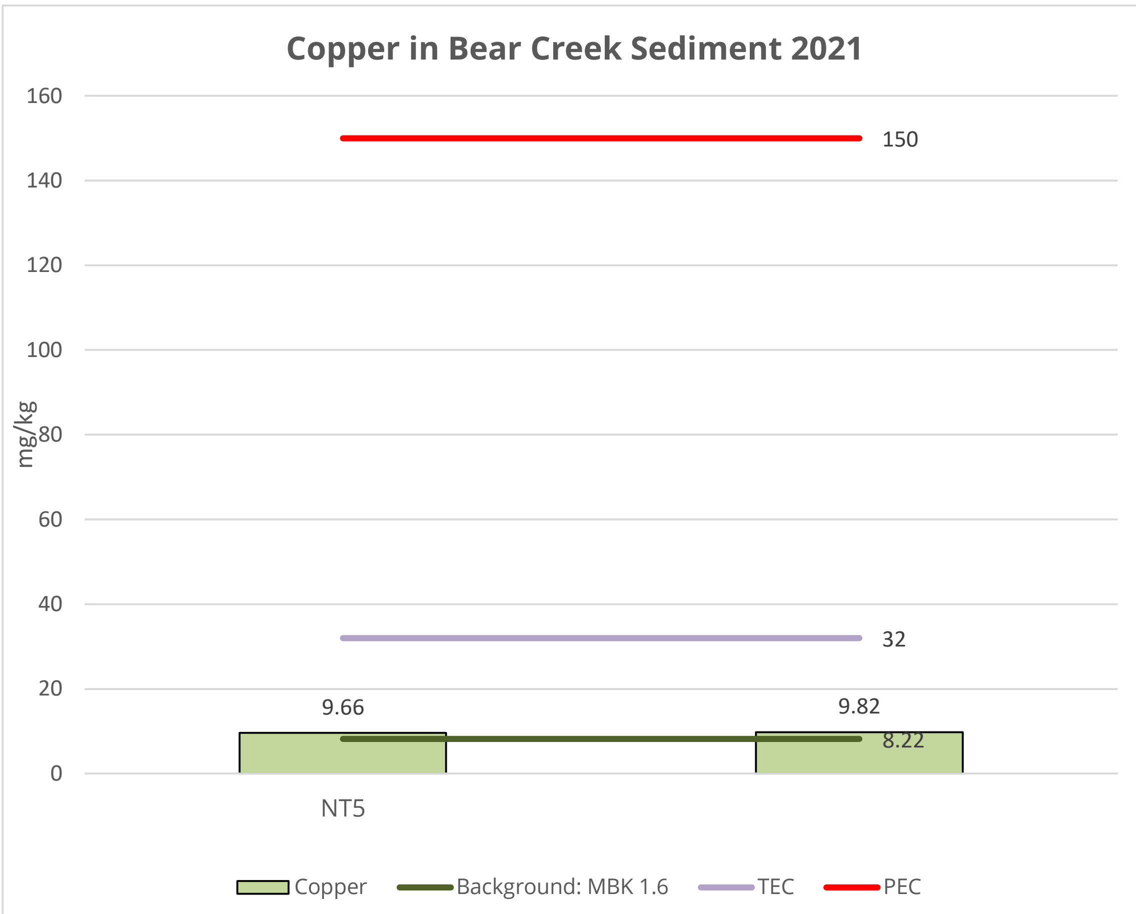


**Figure 10.1.6: Sediment Copper**

## Lead (Sediment)

Bear Creek sediment lead content was not a matter of concern. Lead values were much lower than the CBSQGs (Figure 10.1.7). Lead was once used as a gasoline additive before it was banned in 1995; prior to this time, it was a major atmospheric pollutant. Lead-based paints were used for houses and other buildings prior to 1978 and there are still cases of children being poisoned by the ingestion of paint chips in older homes (CDC 1991). Since lead adsorbs strongly to most soils, soils and sediments can be major sinks for lead in the environment.

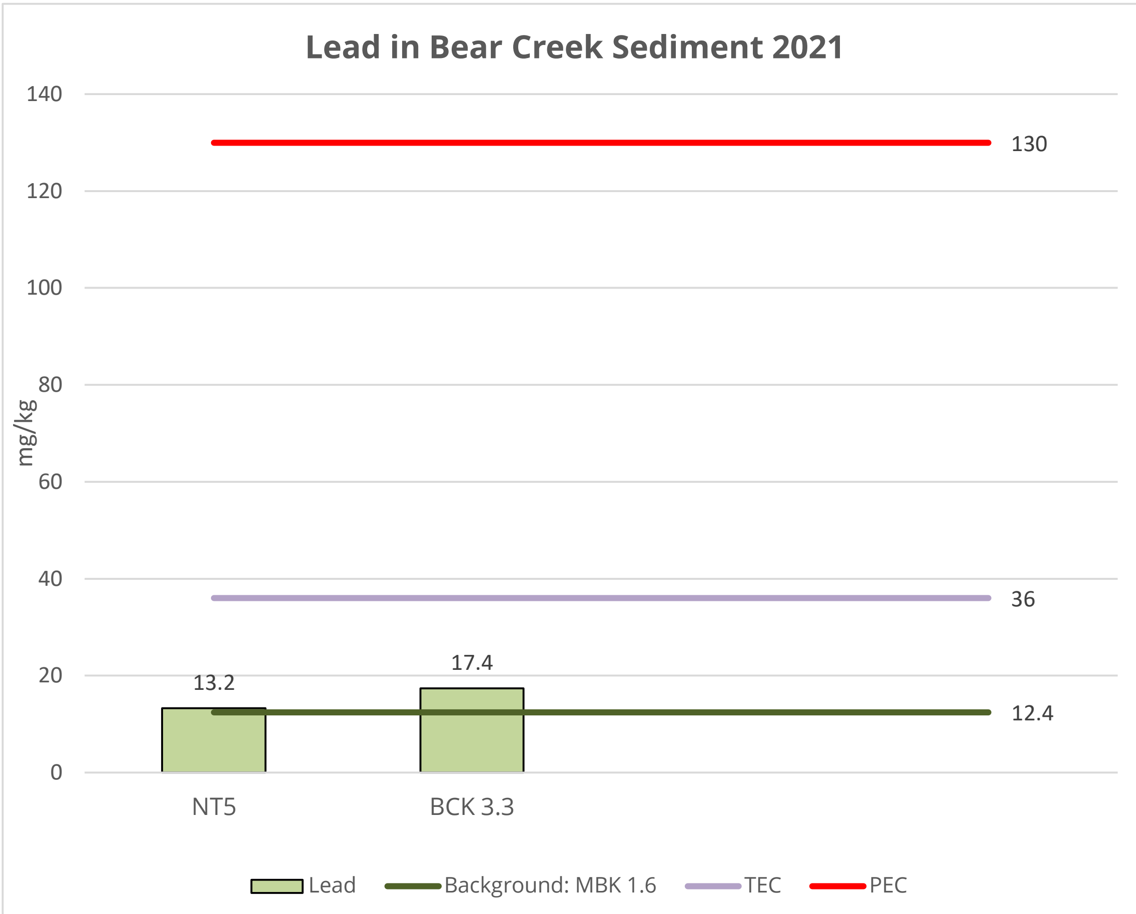


**Figure 10.1.7: Sediment Lead**

**Mercury (Sediment)**

The mercury value for BCK 3.3 was higher than the TEC (Figure 10.1.8). Metals found at levels above the TECs indicate that the metal(s) in question may be adversely affecting benthic macroinvertebrate populations. The mercury value for NT-5 sediment was less than the TEC but almost twice the value of the background site. Mercury occurs naturally in the environment as metallic mercury (elemental mercury), inorganic mercury (mercuric sulfide and mercuric chloride), and organic mercury (methylmercury). Large quantities (11 million kilograms) of elemental mercury were used at the Y-12 plant from 1950 to 1963 for a lithium isotope separation process (Brooks and Southworth 2011). Anthropogenic releases of mercury are predominantly emissions to the air from fossil fuel combustion, mining, and smelting. Solid waste incinerators also contribute releases of mercury. A smaller fraction of the anthropogenic contribution is agricultural mercury-containing fungicides used up until the 1970's and municipal solid waste containing old batteries, electrical switches, and thermometers. Methylmercury is a major health concern because it accumulates in fish and aquatic mammals to a great extent. Where elemental mercury is present, most methylmercury in the environment is produced by bacteria and fungi (ATSDR 1999).

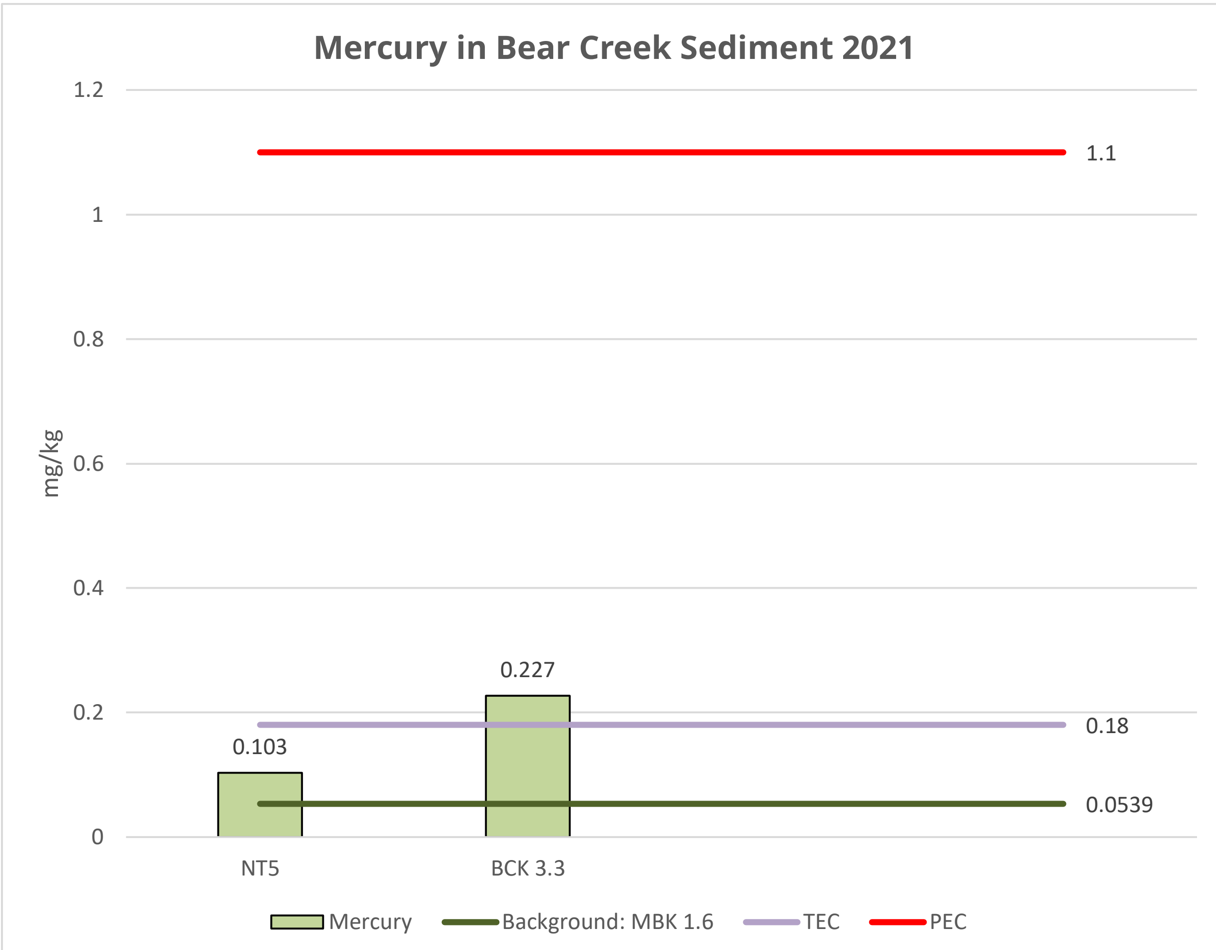


**Figure 10.1.8: Sediment Mercury**

### Uranium (Sediment)

Uranium was greater than background at the Bear Creek sites (Figure 10.1.9). There are no CBSQGs established for uranium. Uranium is a dense, silver-white, radioactive metal in its pure state. It is found in the environment in rocks, soil, water, and air in very small amounts. Phosphate fertilizers usually contain considerable amounts of uranium due to the materials from which they are made. Mining and erosion from mine tailings can result in increased amounts of uranium in the environment. Uranium became more prevalent in the environment with the development of nuclear energy applications, such as nuclear power plants and weaponry. A large quantity of uranium was used at the Oak Ridge Gaseous Diffusion Plant (former K-25 site) and most of the uranium waste was buried in landfills in the Bear Creek Valley. Uranium has also been used at the Oak Ridge Y-12 plant. Exposure to small amounts of natural uranium is not particularly dangerous. People who are exposed to high amounts of uranium, particularly enriched uranium, have a chance of developing cancer (ATSDR 2013).

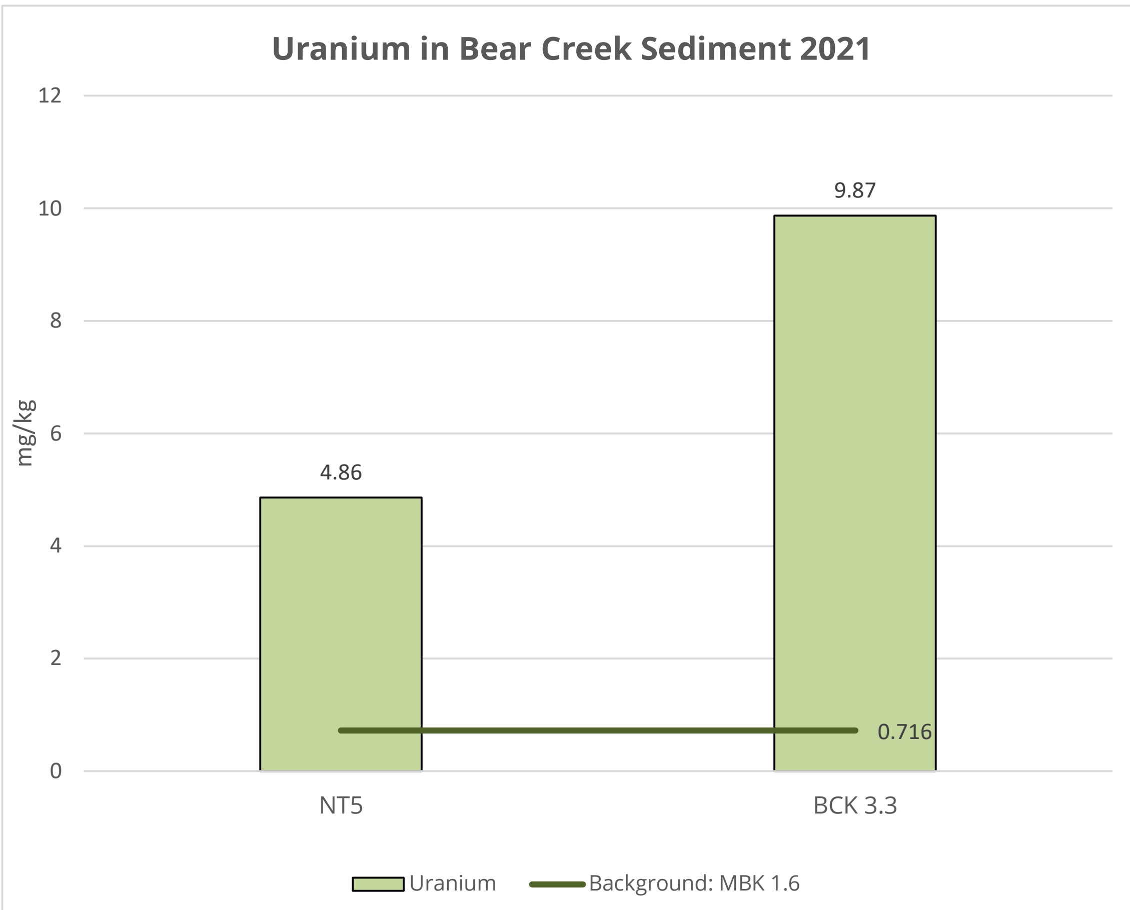


**Figure 10.1.9: Sediment Uranium**

### Gross Alpha (Sediment)

Gross alpha activity has been above background for most previous years at the Bear Creek sediment sites but decreased to levels near background in 2021 (Figure 10.1.10). The gross alpha background value is the mean of three years data (2018, 2019, and 2021).

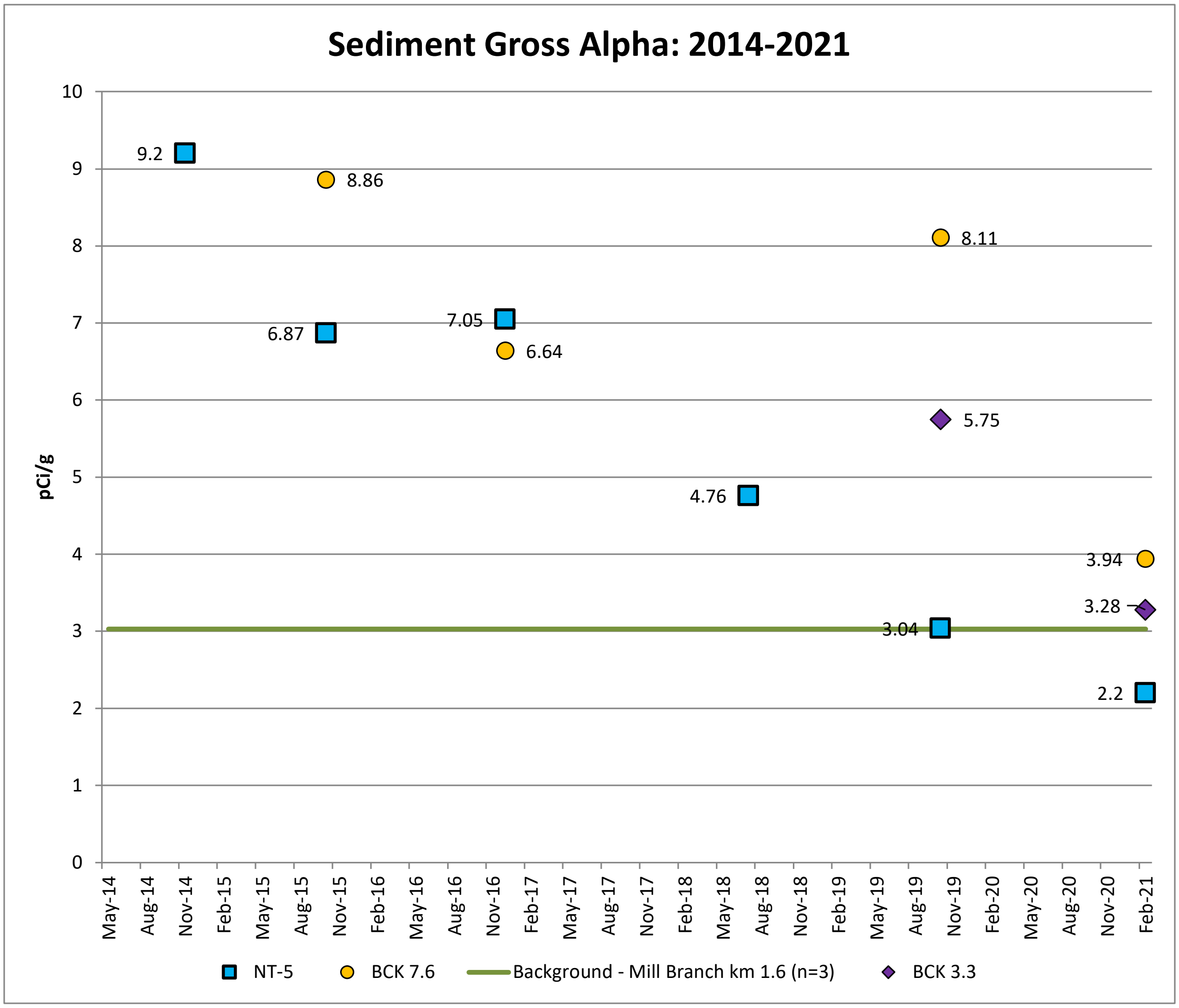


**Figure 10.1.10: Sediment Gross Alpha**

**Gross Beta (Sediment)**

While BCK 3.3 and 7.6 have been consistently above background over the years 2015-2021, gross beta at NT-5 increased dramatically in 2019 and 2021 (Figure 10.1.11). This is probably a result of the disposal of technetium-99 (Tc-99) containing wastes at the EMWMF. Of 68 surface water samples taken at the V-Weir at EMWMF in 2019, Tc-99 was detected in 67 with a minimum of 11.5 pCi/L and a maximum of 1800 pCi/L. The annual mean was 326 pCi/L (DOE 2020).

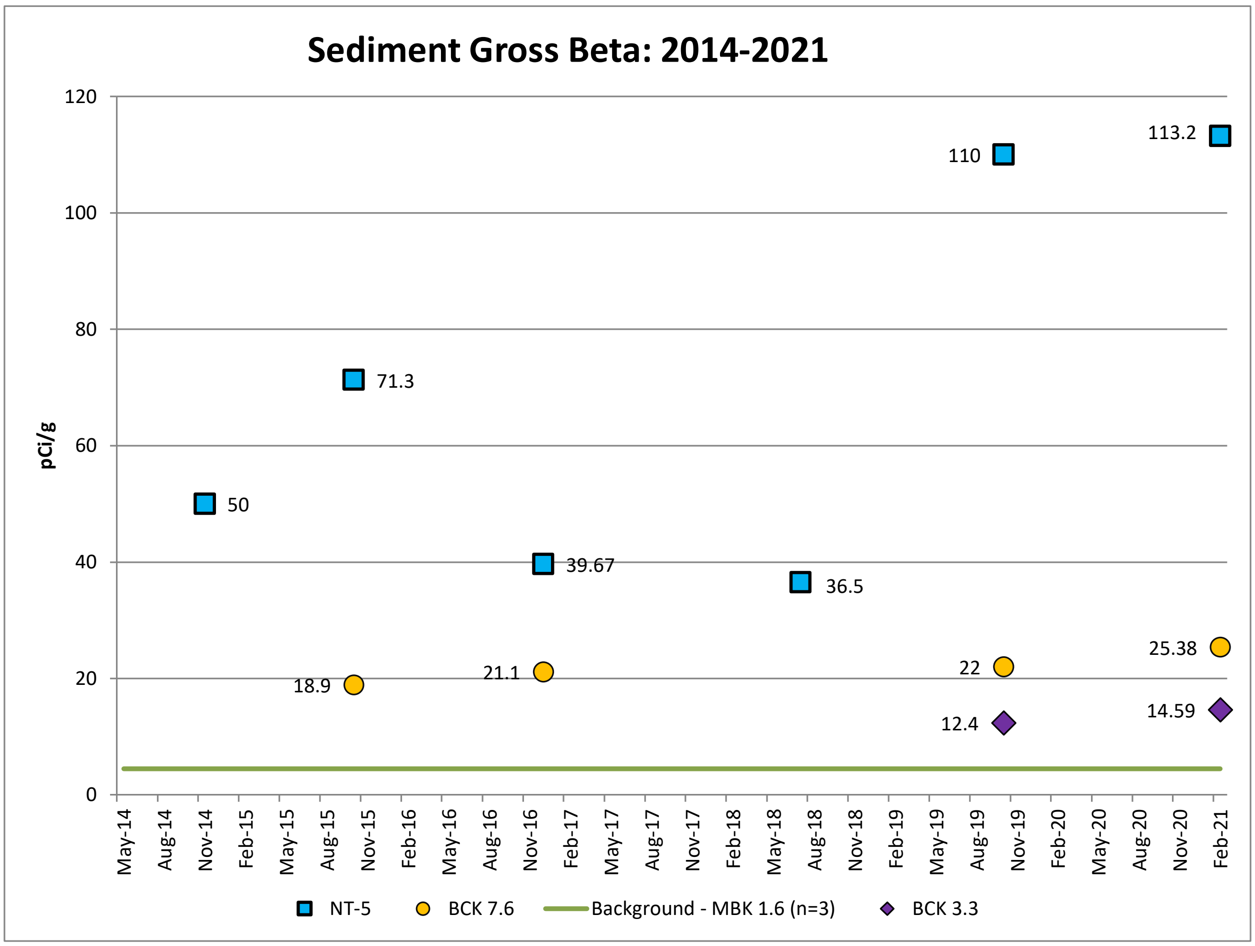


**Figure 10.1.11: Sediment Gross Beta**

## Uranium Isotopes (Sediment)

In all cases the uranium isotope data were above background. Uranium-234 (U-234) and U-235 activity was greatest at NT-5 and decreased downstream (Figures 10.1.12 and 10.1.13). U-238, on the other hand, was lowest at NT-5 (2.32 pCi/L) and the highest activity (6.93 pCi/L) was found at BCK 7.6. At BCK 3.3, the U-238 activity dropped to 3.84 pCi/L (Figure 10.1.14).

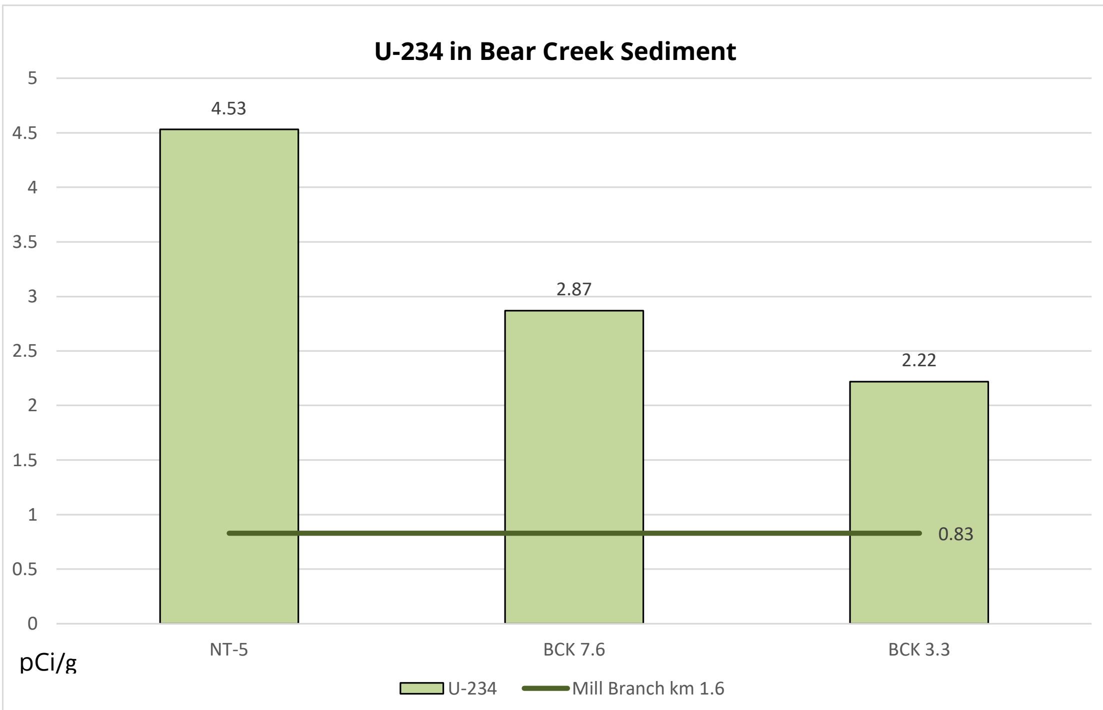


**Figure 10.1.12: Sediment U-234**

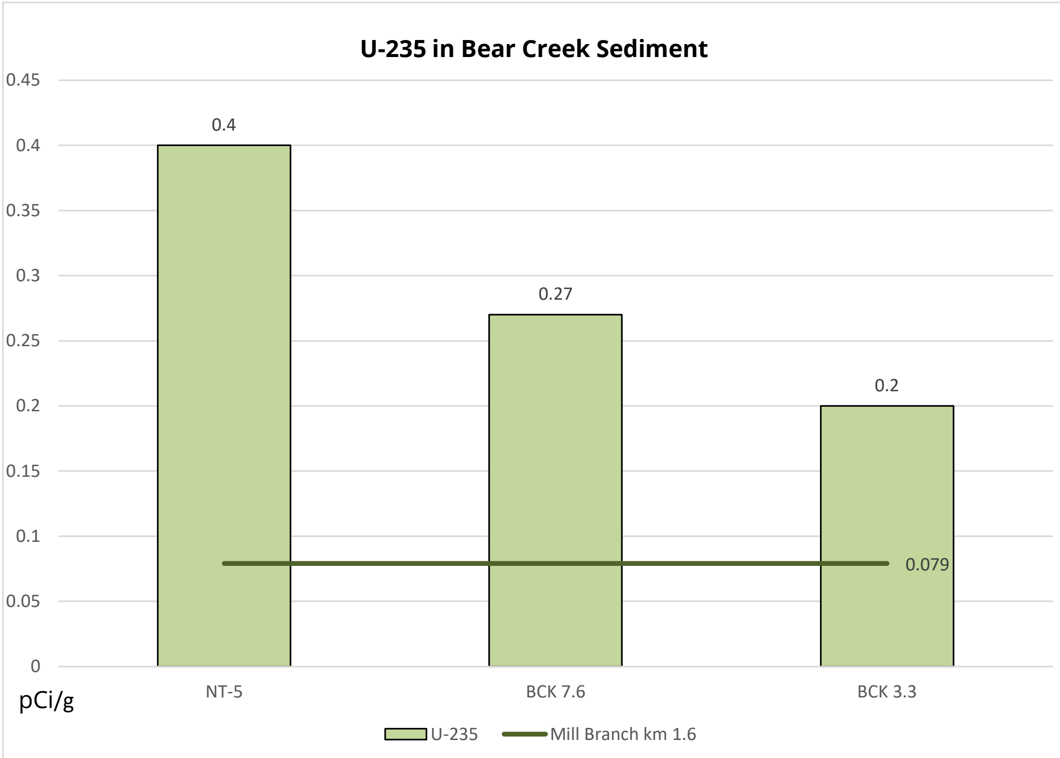


**Figure 10.1.13: Sediment U-235**

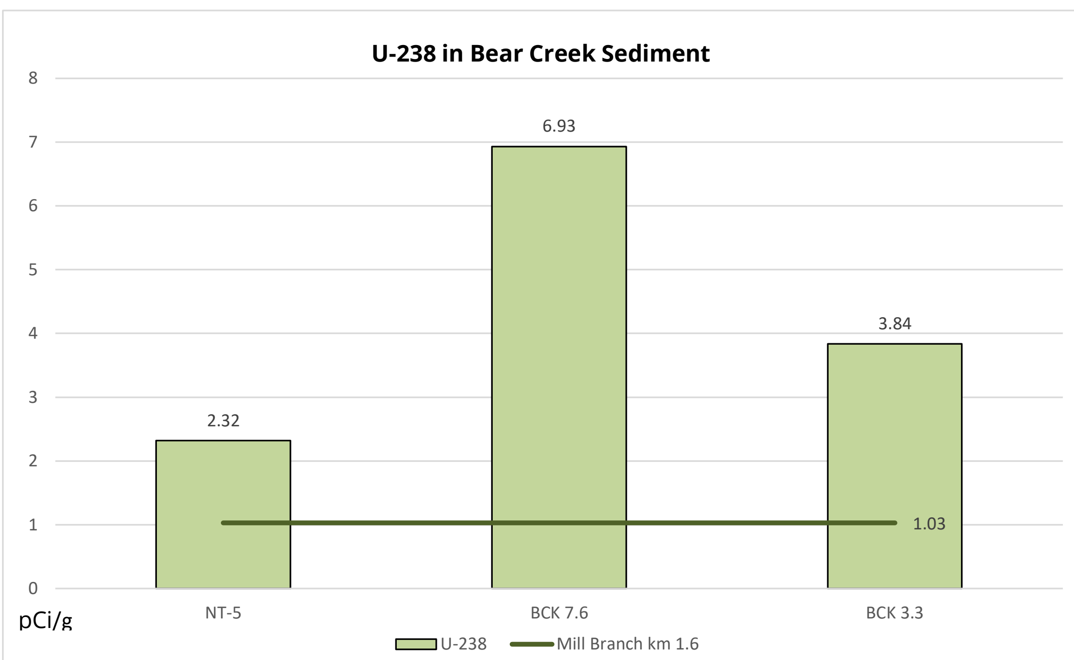


**Figure 10.1.14: Sediment U-238**

### Surface Water

Surface water (SW) samples were collected at Bear Creek in May 2019 at BCK 12.3, BCK 9.6, and BCK 3.3. MBK 1.6 was also sampled to obtain background data for comparison to the Bear Creek data. The primary contaminants of concern were nitrate and uranium (Figures 10.1.15, 10.1.16). Arsenic, cadmium, chromium, selenium, and zinc were not detected in Bear Creek surface water and a trace of copper (0.31 µg/L) was found only at BCK 12.3. Mercury was detected at BCK 12.3 and 9.6 but only in trace amounts and much less than the Tennessee Water Quality Criteria (0.051 µg/L).

### Inorganic nitrogen – nitrate/nitrite (SW)

Nitrate/nitrite was high (27.1 mg/L) at BCK 12.3 and exceeded the drinking water maximum contaminant level (MCL) of 10 mg/L (Figure 10.1.15). Although Bear Creek does not have the use classification as a source of drinking water, the MCL was used in this study for perspective. Nitrate/nitrite was also elevated (6.58 mg/L) at BCK 9.6. The inorganic nitrogen is due to shallow groundwater contamination from the former S-3 ponds site upgradient of BCK 12.3. The former S-3 ponds site is a series of unlined pond areas previously used for managing liquid waste. The ponds were capped under the Resource Conservation and Recovery Act (RCRA) and converted to a parking lot. The former S-3 ponds site is a source of uranium, technetium, and nitrate contamination in Bear Creek.

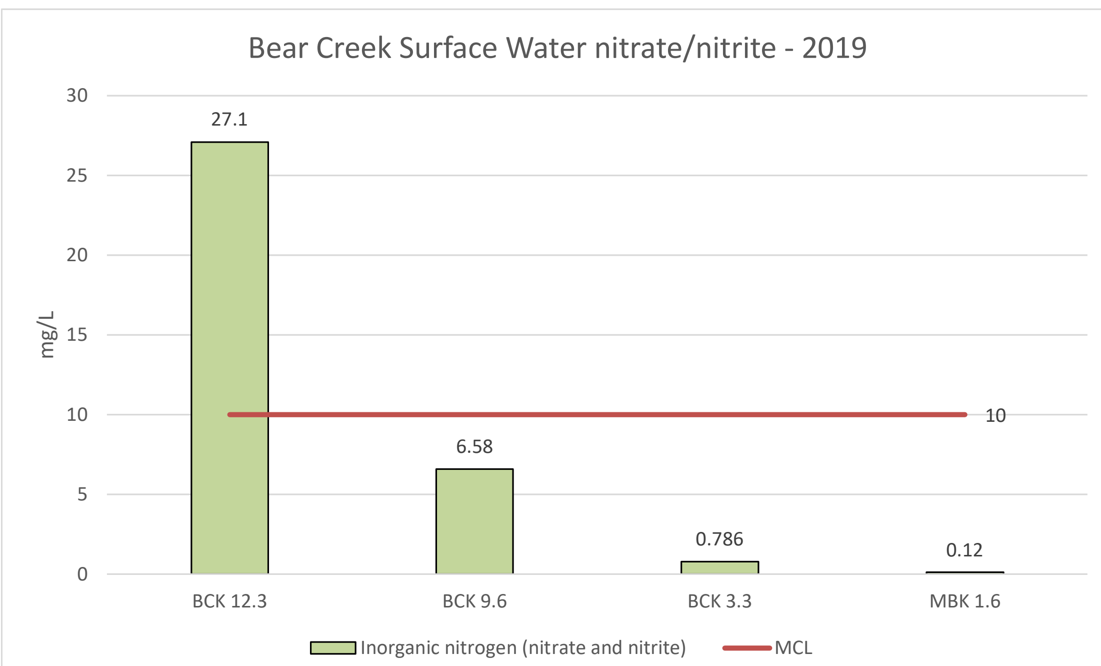


**Figure 10.1.15: Surface water inorganic nitrogen (nitrate/nitrite)**

**Uranium (SW)**

Bear Creek uranium concentrations exceeded the MCL (30 µg/L) at BCK 12.3 and 9.6 (Figure 10.1.16). In previous years, uranium was disposed at the S-3 ponds and infiltrated the shallow groundwater around BCK 12.3. In addition, considerable uranium was disposed at the Bear Creek Burial Grounds (BCBGs) which are farther down gradient in the Bear Creek Valley.

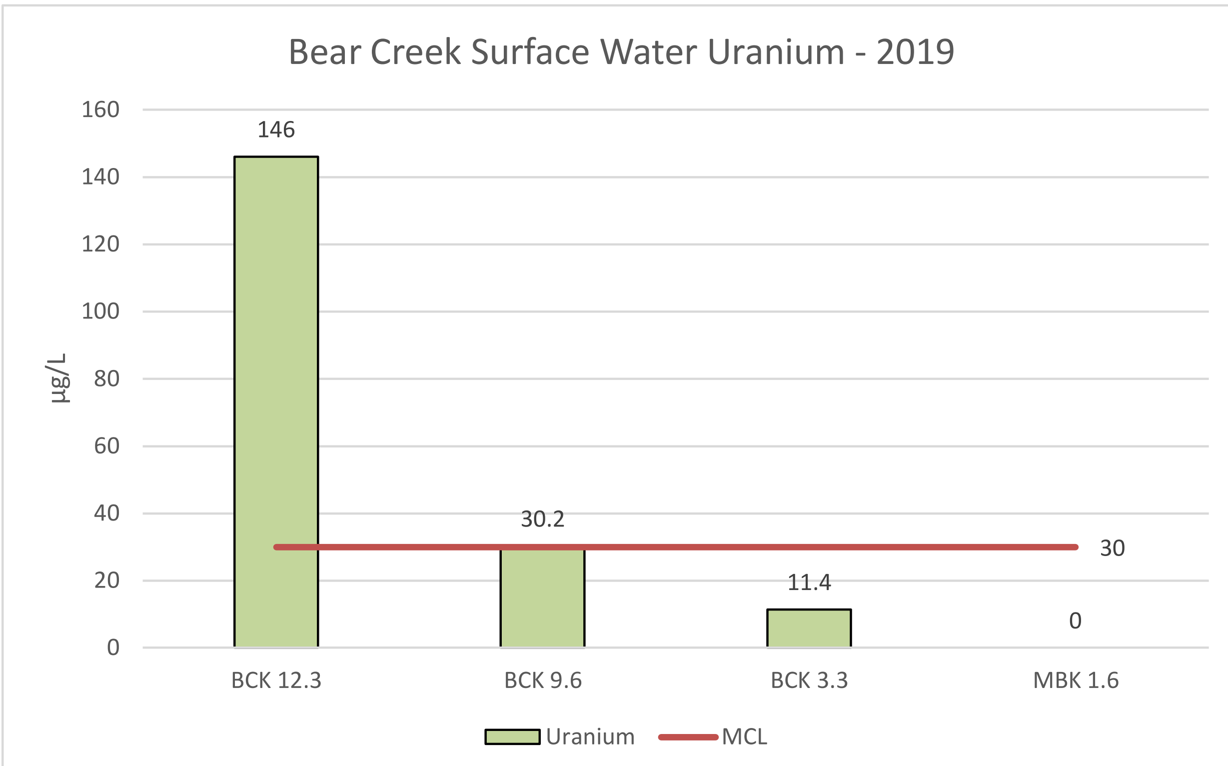


**Figure 10.1.16: Surface water uranium**

**Gross alpha (SW)**

The gross alpha concentration exceeded the EPA MCL of 15 pCi/L at BCK 12.3 (Figure 10.1.17). As Bear Creek does not have a designated use as a drinking water source, the MCL was used for comparison. This gross alpha activity was attributed to the uranium in the creek water. The influx of uranium-contaminated shallow groundwater from the former S-3 ponds site explained the high gross alpha activity observed at BCK 12.3. At BCK 9.6, the gross alpha activity may be the residual from the upstream reaches of the stream; this site may also be receiving a gross alpha boost from uranium escaping the BCBGs through the North Tributary-7 (NT-7) pathway.

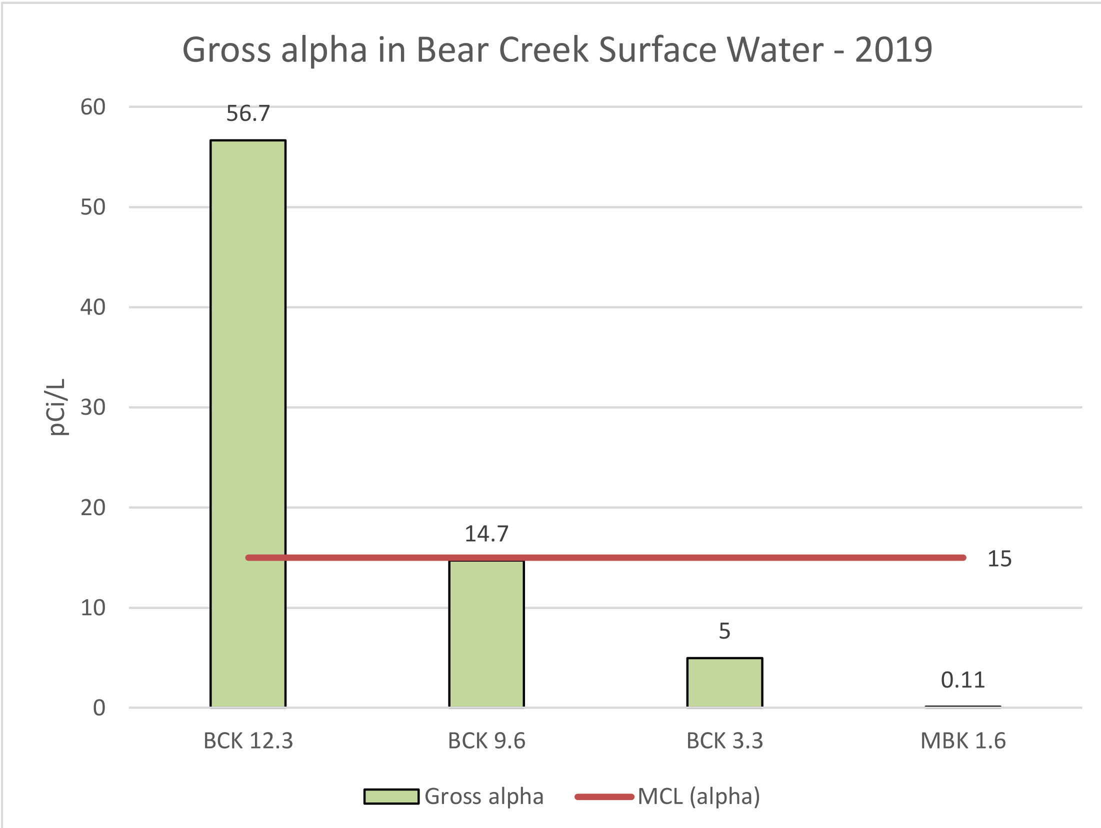


**Figure 10.1.17: Surface water gross alpha**

**Gross beta (SW)**

Gross beta concentrations were elevated at BCK 12.3 and BCK 9.6 from at least two sources. One source, the S-3 Ponds site, was where uranium and other radionuclides were disposed of in four unlined ponds. These ponds were stabilized and capped with a RCRA cap over the area and covered with asphalt to make a parking lot in 1988, but there were large releases. Another source is the Bear Creek Burial Grounds, which add to the contribution at BCK 9.6. Both the U-238 and U-235 decay series produce several beta-emitting daughter nuclides with very short half-lives, (e.g., bismuth-214 (Bi-214) and lead-214 (Pb-214) and thus are very radioactive in surface water at BCK 9.6 and BCK 12.3 (Figure 10.1.18).

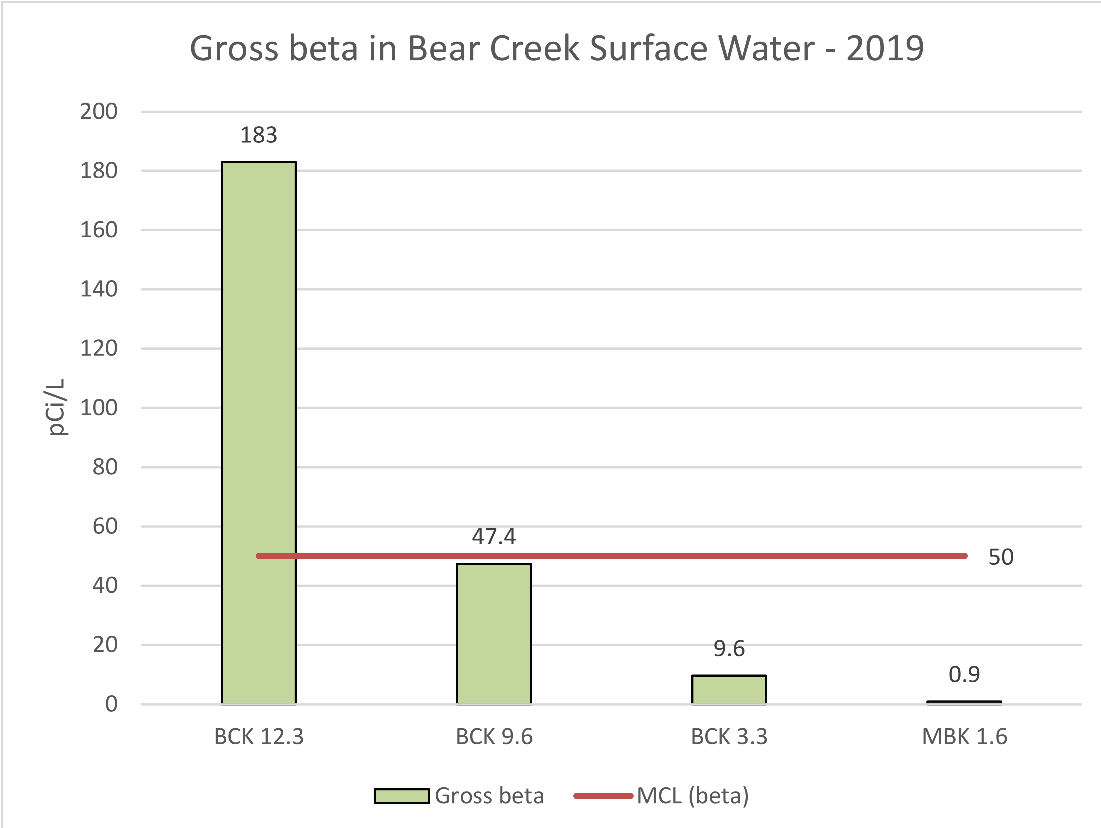


**Figure 10.1.18: Surface water gross beta**

**Uranium isotopes (SW)**

The MCL for isotopic uranium (U-234, U-238) was exceeded only at BCK 12.3 (Figure 10.1.19). All of the other site concentrations were below the MCL of 20 pCi/L. Although Bear Creek does not have the designated use as a drinking water source, the MCL was used for comparison.

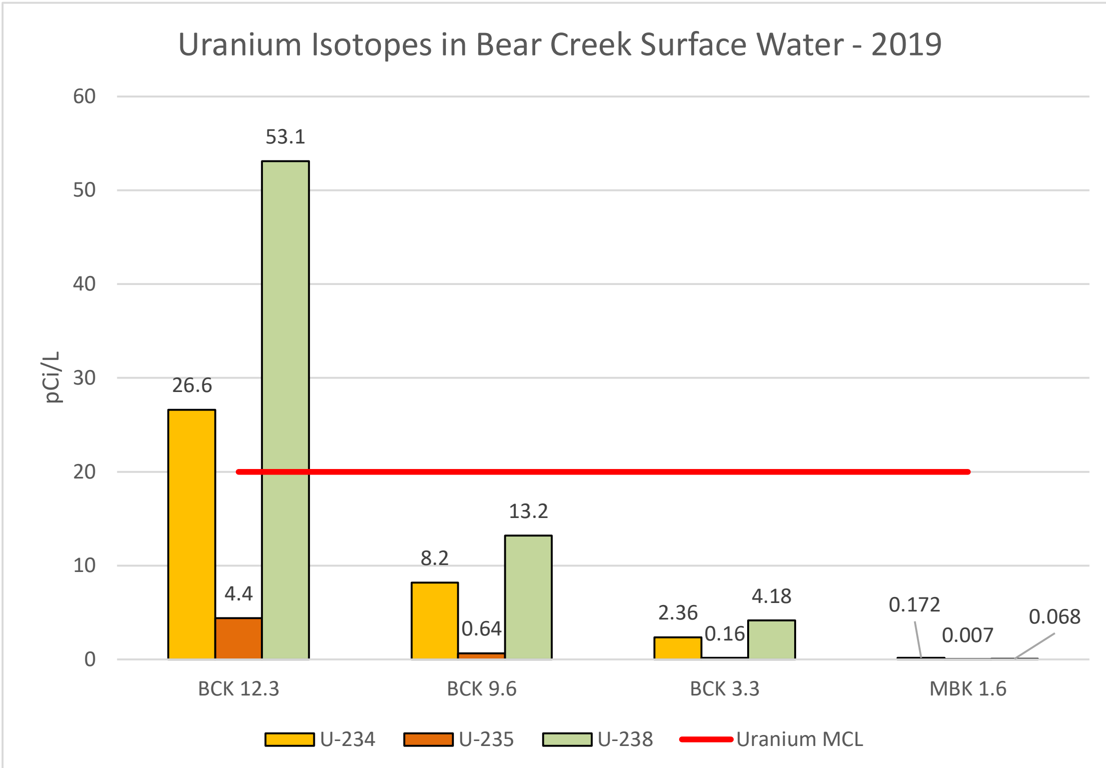


**Figure 10.1.19: Uranium isotopes**

### Technetium-99 (SW)

Technetium-99 (Tc-99), a beta emitter, was among the waste materials disposed of at the former S-3 ponds, and its presence there may contribute to the elevated gross beta activity at BCK 12.3 (Figure 10.1.20). The activity of the Tc-99 at all of the Bear Creek sites was well below the MCL (900 pCi/L). Technetium-99 has been detected in the water discharge from the V-Weir at the EMWMF. This water flows into North Tributary 5 (NT-5) of Bear Creek and could account for the elevated gross beta activity observed at BCK 9.6.

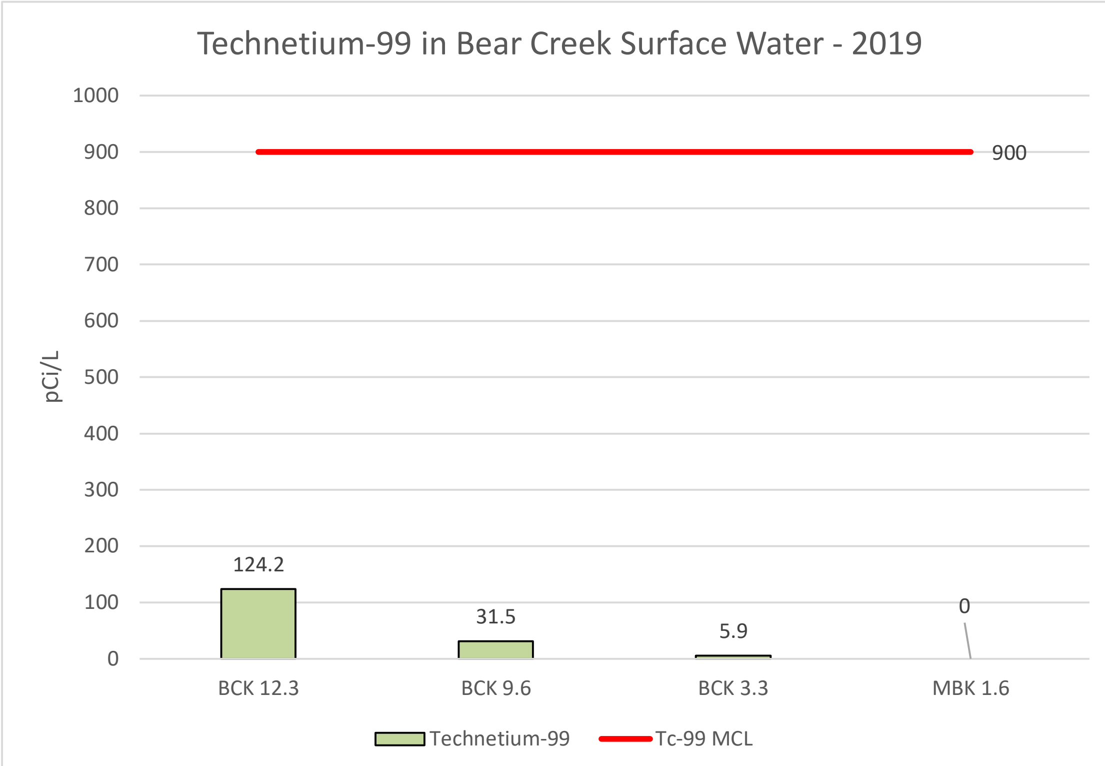


**Figure 10.1.20: Technetium-99**

### Surface Water Toxicity/Biomonitoring (SW)

Toxicity and biomonitoring tests were conducted for surface water at the following Bear Creek sampling sites: BCK 12.3, 9.6, 7.6, 4.5, and 3.3 (Figure 10.1.21). In addition, testing was also conducted at the mouth of Bear Creek at East Fork Poplar Creek km 2.2 (EFK 2.2), as well as at the background site, Hinds Creek km 20.6 (HCK 20.6). *Ceriodaphnia dubia* (water flea) was the organism used for testing survival and reproduction in Bear Creek effluent. *Ceriodaphnia dubia* (water flea) - inhibition was demonstrated at BCK 12.3 (Figure 10.1.21). Using the Linear Interpolation Method, the IC25 (inhibition concentration causing a 25% reduction in survival or reproduction of the test organisms) is reported as being greater than (>) 100% effluent for survival and equal to 26.8% effluent for reproduction. The overall IC25 is reported as being the lesser of the two values (26.8% effluent). Since the IC25 result (26.8% effluent) was less than 100% effluent, the effluent is considered to be toxic to the daphnia (reproduction) at BCK 12.3. All of the other sites tested perfectly (IC25 = >100%) for the daphnia tests.

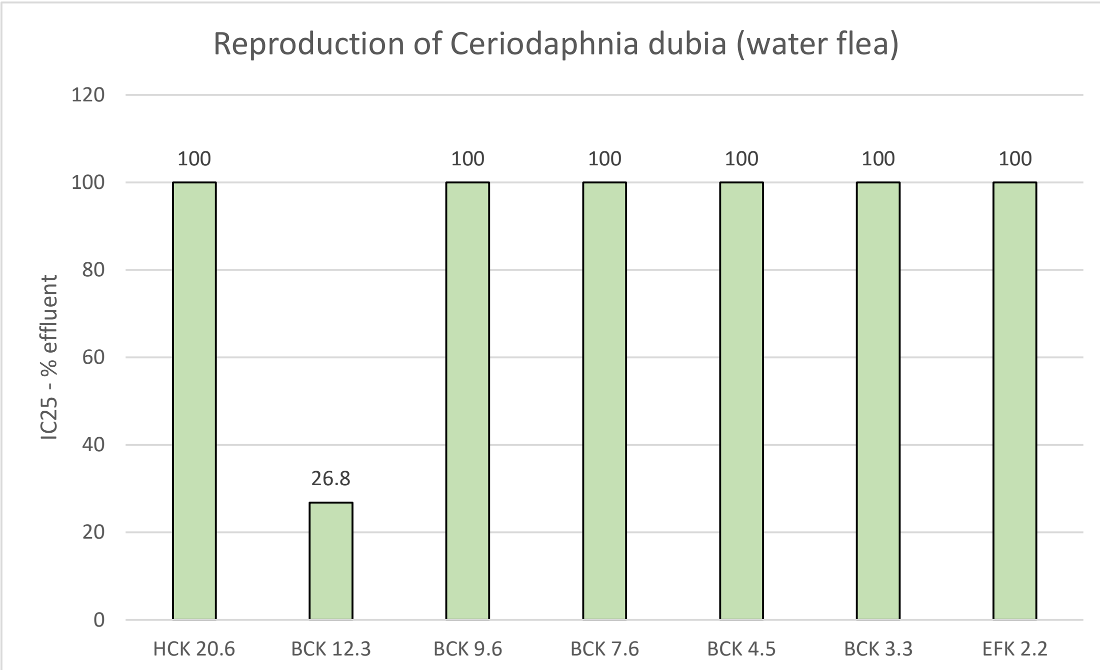


**Figure10.1.21: Reproduction of Ceriodaphnia dubia (water flea)**

*Pimephales promelas* (fathead minnow) was used for testing survival and growth at the same sampling sites (Figure 10.1.22). Inhibition was demonstrated at two sites: BCK 3.3 and EFK 2.2. The effects of an effluent in chronic toxicity tests are estimated based on the calculation of the IC25. The IC25 value is a statistical calculation of the effluent concentration which causes a 25% reduction in growth or reproduction of test organisms. At BCK 3.3, the IC25 is 39.3%, which is the value for growth; the IC25 survival value was (>)100%. The worst performing site was EFK 2.2, with a IC25 of 21.8% (growth); the IC25 for survival here was 56.3%. EFK 2.2 samples were collected at the mouth of Bear Creek (BCK 0.0). The reasons for the poor performance of BCK 3.3 and EFK 2.2 are not known; more toxicity/biomonitoring testing is warranted to confirm these results.

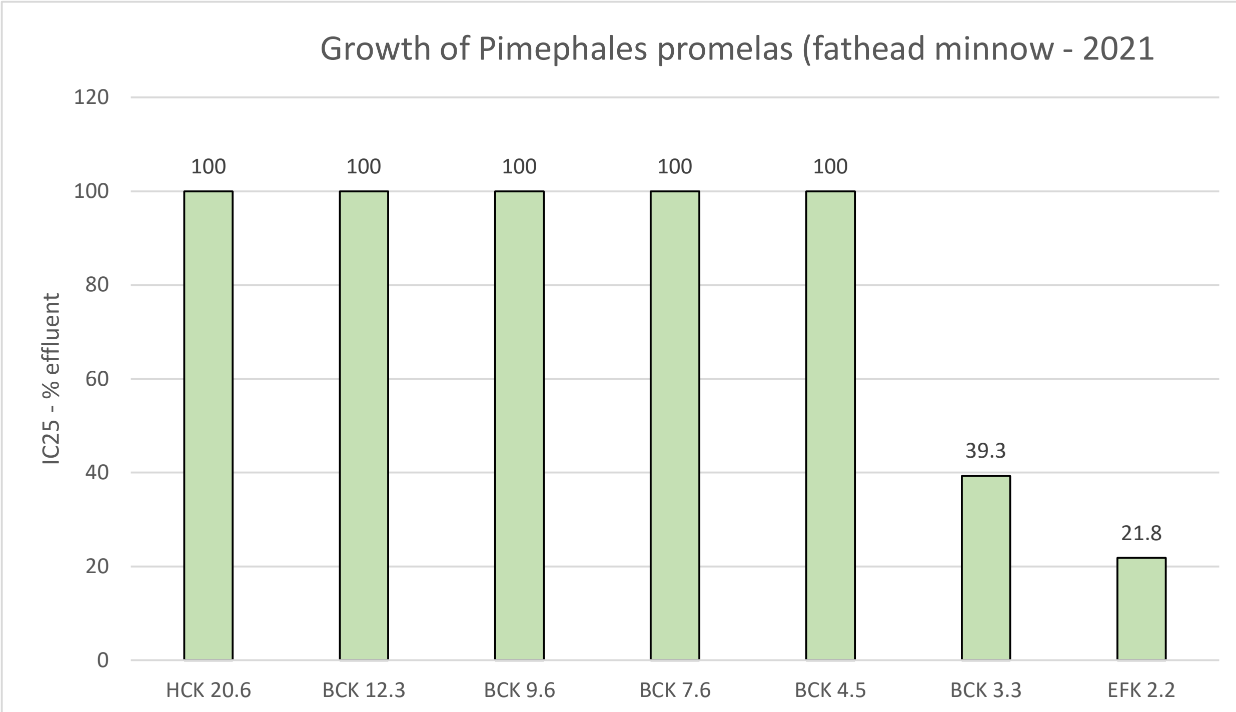


**Figure 10.1.22: Growth of Pimephales promelas (fathead minnow)**

### Soils

Soil samples were collected at four locations on Bear Creek (BCK 11.97, 9.6, 7.87, and 3.3) and at a background location, Pinhook Branch (PBK 1.6). Samples were collected by the consulting firm, Civil & Environmental Consultants, Inc. (CEC), using Incremental Sampling Methodology (ISM) using a grid of 30 1-meter square cells at each of the sites. The locations of the approximate center of the grids are shown in Table 10.1.2. Justifications for choosing these locations are below:

- Bear Creek Kilometer 3.3 – this location captures radionuclide inputs from sources in Bear Creek Valley and the west end of the Y-12 National Security Complex that discharge into the headwaters of Bear Creek. This location is downstream of the Environmental Management Waste Management Facility (EMWMF) and the proposed Environmental Management Disposal Facility (EMDF).
- Bear Creek Kilometer 7.87 – this location is in an area of Bear Creek that drains the area where the proposed EMDF will be built. Sampling here helps establishe a baseline for comparisons with future data.
- Bear Creek Kilometer 9.6 – this location receives drainage from the vicinity of the Bear

Creek Burial Grounds and EMWMF. Sampling here provides assessment of the soil at this location.

- Bear Creek Kilometer 11.97 – this location in the headwaters of Bear Creek is adversely affected by shallow groundwater contaminated from wastes buried at the former S-3 ponds site. This soil sample is collected downstream of the channelized portion of the stream that resembles a ditch.

- Pinhook Branch Kilometer 1.6 – Pinhook Branch is an unimpacted tributary of East Fork Poplar Creek. The soils data obtained from this location are valuable for comparisons to the Bear Creek data.

Since the samples were analyzed for PFAS, special care was taken to prevent the contamination of the samples inadvertently. Staff used the guidelines from the PFAS Soil Sampling Guidance document issued by the Michigan Department of Environmental Quality (November 2018) to choose PFAS-free clothing and footwear for the field sampling work (MDEQ 2018).

Overall, sampling was conducted in accordance with the Interstate Technology Regulatory Council (ITRC) Incremental Sampling Methodology (ISM) document dated February 2012 and the Incremental Sampling Methodology (ISM) Update document dated October 2020. Incremental sampling uses a normalized composite sampling and processing approach to reduce variability. ISM provides a relatively unbiased representation of the average constituent concentration in the sample material and over the assessed area. This approach leads to more consistent and reproducible results that are representative of the assessed area. A sample grid was staked out at each of the five sample locations and a 30-point bulk sample was collected for laboratory processing and subsampling (Figures 10.1.23 and 10.1.24).

**SAMPLE FIELD SKETCH**

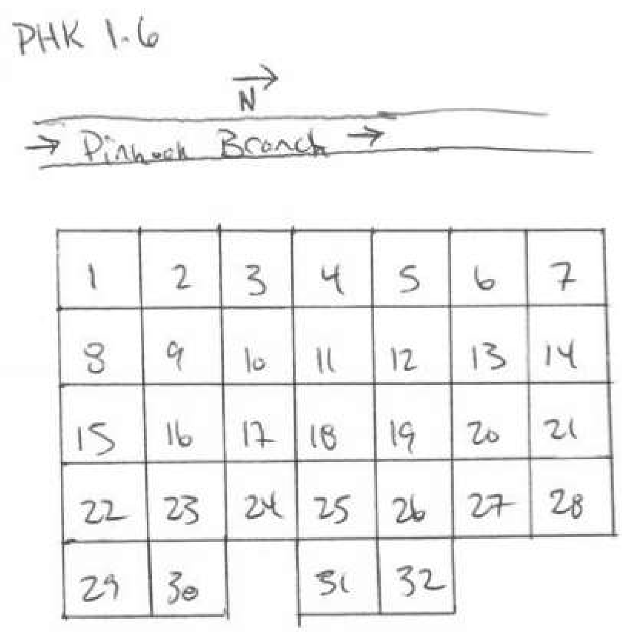


**Figure 10.1.23: Example of a sampling grid (PBK 1.6)**

**Figure 10.1.24: Staked sample grid at PBK 1.6**

Soil sampling equipment consisted of nickel-plated metal sampling tubes that were purchased new from JMC Soil for the sampling event. A 6-inch depth was marked on the sampling tubes with a metal file. Sampling tubes were first washed with a solution of ThermoFisher Scientific certified PFAS-free water and Alconox, then rinsed with PFAS-free water. The PFAS-free water used for equipment decontamination was Optima-LCMS Grade Water (Lot 206858). After cleaning, sampling tubes were left to air dry and then placed into gallon-size Ziploc brand bags. Soil samples were placed directly into laboratory-provided containers. Sample containers provided for this project were QEC 64 oz. HDPE wide-mouth sample containers (Lot 0-083-01BB). Equipment and sample containers were shuttled to and from the sample locations in food-grade 5-gallon buckets that had been washed with a solution of PFAS-free water and Alconox and then rinsed with PFAS-free water (CEC 2021).

Sample increments were collected using a JCM Backsaver Handle outfitted with a dedicated 1.25- inch inside diameter core barrel that had been marked with a metal file for sampling to a depth of 6 inches. Sample increments were removed from the core barrel with a dedicated wooden paint stirrer. New core sampler barrels were purchased for each site and pre-cleaned using a solution of ThermoFisher Scientific certified PFAS-free water and Alconox followed by a rinse with PFAS free water (CEC 2021).

Beginning with the grid cell designated as cell 1, an approximately 6-inch-deep soil increment was collected for the TDEC-DoR-OR sample from a random quadrant as determined using a random number generator tool in Microsoft Excel. Random secondary, tertiary, and quaternary quadrant selections were also available in the event that a full increment could not be collected from any cell due to obstructions such as roots or rocks. TDEC-DoR-OR sample increments were removed from the soil corer with a dedicated wooden paint stirrer and/or a gloved hand and placed directly into a labeled, laboratory-provided PFAS-free bulk container. At locations where a field duplicate or matrix spike/matrix spike duplicate sample was being collected by TDEC-DoR-OR, additional increments were subsequently collected from the same quadrant and placed into the respective containers. Finally, a soil increment was collected from the same cell and quadrant for the DOE sample. DOE increments were placed directly into a dedicated 5-gallon bucket that was provided by DOE. After all TDEC-DoR-OR and DOE increments had been collected from cell 1, this process was repeated in each subsequent cell until 30 increments had been collected (CEC 2021).

The TDEC-DoR-OR soil samples were processed by Pace Analytical Laboratory according to strict ISM protocols and were analyzed for metals, radionuclides, and organics (semivolatiles, pesticides, PCBs, and PFAS).

**Table 10.1.2: Soil Sampling Site Locations**

| Site | Latitude | Longitude |
|---|---|---|
| BCK 11.97 | 35.971489 | -84.279735 |
| BCK 9.6 | 35.960040 | -84.297500 |
| BCK 7.87 | 35.950622 | -84.313795 |
| BCK 3.3 | 35.943437 | -84.349457 |
| PBK 1.6 | 35.963495 | -84.326492 |

Semivolatile analysis detected 14 polycyclic aromatic hydrocarbons (PAHs) in the Bear Creek Samples that were not found at the background site, PBK 1.6. However, three PAHs were present at PBK 1.6: 2-methylnapthalene, fluoranthene, and naphthalene. PAHs can be formed naturally from wildfires, bacterial and algal synthesis, erosion of sedimentary rocks containing petroleum hydrocarbons, and leaf litter decomposition (Abdel-Shafy 2015). None of the semivolatile results exceeded the U.S. EPA's Regional Screening Levels (RSLs) for residential direct contact exposure with a target cancer risk of $10^{-6}$ and a target hazard quotient of 0.1. Pesticide analysis showed no detections above the method detection limits (MDLs). Arochlors (PCB mixtures) were not detected at PBK 1.6; Arochlor 1260 was quantified in each of the Bear Creek sites at a level below the EPA RSLs for residential soil under the direct contact exposure scenario (Figure 10.1.25). The maximum arochlor 1260 result was 0.223 mg/kg at BCK 7.87; it's RSL is 0.24 mg/kg (Figure 10.1.25). The BCK 7.87 site is influenced by groundwater contamination from the Bear Creek Burial Grounds.

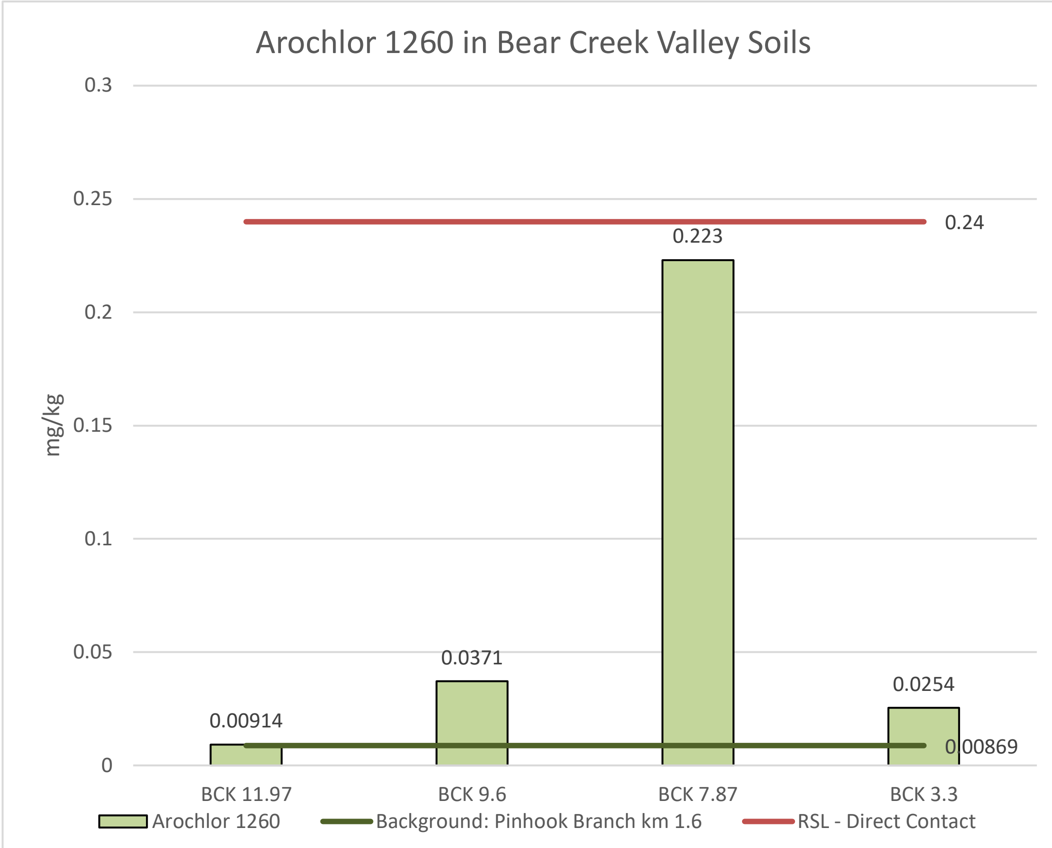


**Figure 10.1.25: Arochlor 1260 in Bear Creek Valley soils**

Metals

All of the metals listed in the requested analytical suite (As, Ba, Be, B, Cd, Cs, Cr, Cu, Pb, Hg, Ni, Se, Sr, U, and Zn), were detected in all the collected samples, with the exception of boron (B) and selenium (Se),

Arsenic and uranium were detected at levels above the RSLs for residential soil under direct contact exposure in all of the samples (Figures 10.1.26, 10.1.27). At PBK 1.6, the arsenic value was detected at levels above its MDL, but below the MQL, thus it is flagged as estimated. At BCK 11.97, the mercury concentration exceeded the RSL (Figure 10.1.28). Cadmium values at the Bear Creek sites were considerably higher than background but below the RSL for direct contact (Figure 10.1.29).

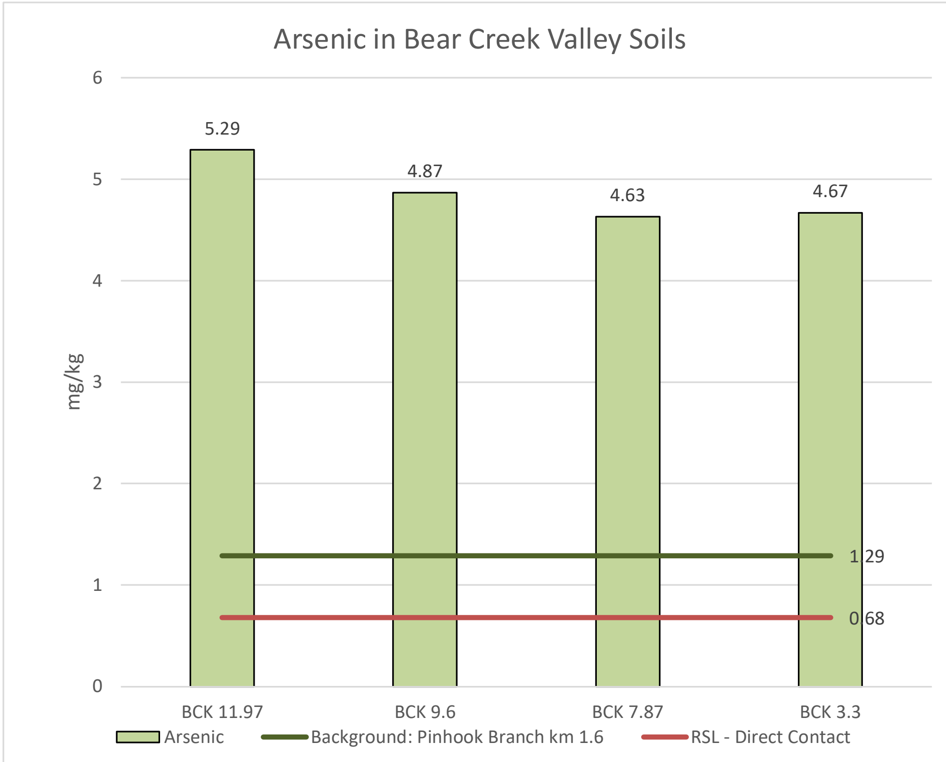


**Figure 10.1.26: Arsenic in Bear Creek Valley Soils**

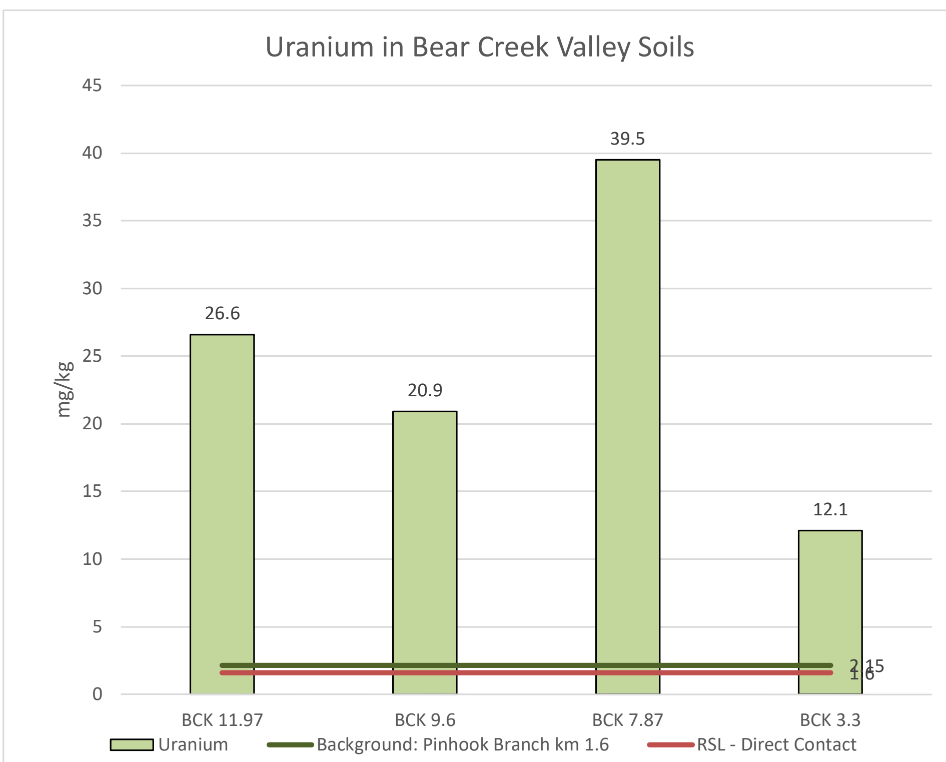


**Figure 10.1.27: Uranium in Bear Creek Valley Soils**

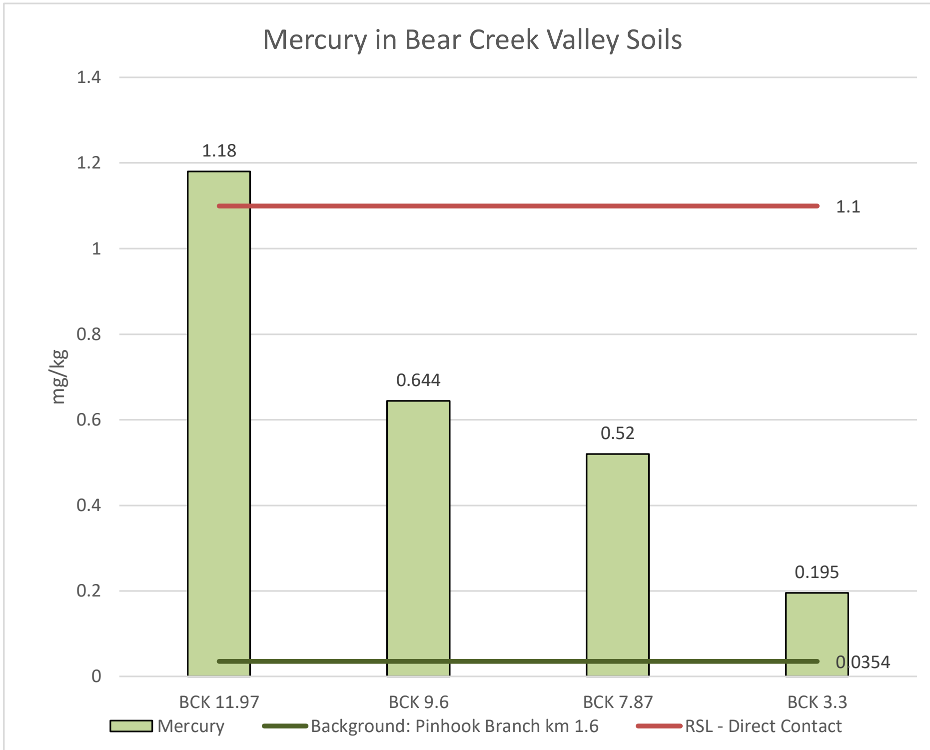


**Figure 10.1.28: Mercury in Bear Creek Valley Soils**

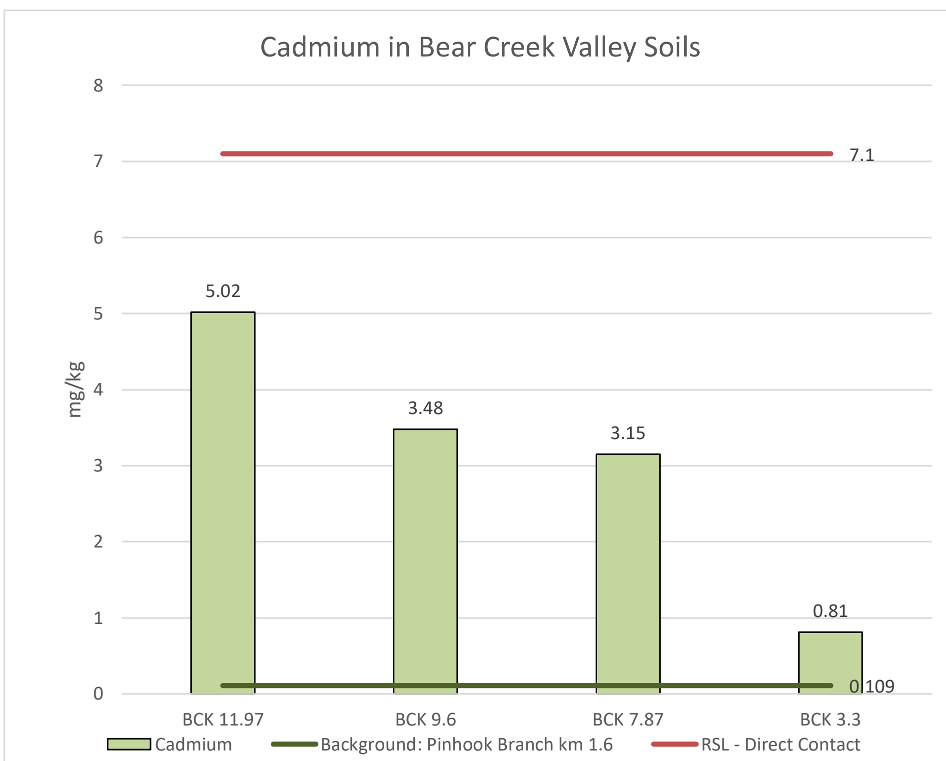


**Figure 10.1.29: Cadmium in Bear Creek Valley Soils**

Several PFAS compounds were detected in all of the samples. Perfluoro-n-butanoic acid (PFBA) was present at all sites, with an estimated value at BCK 11.97. The site with the greatest concentration of PFBA was BCK 9.6 (4 µg/kg) (Figure 10.1.30). Perfluorooctanesulfonic acid (PFOS) was also detected in all of the samples, with estimated values for PBK 1.6 and BCK 3.3. The maximum concentration of PFOS was found at BCK 11.97 (3.7 µg/kg) (Figure 10.1.31). Seven additional PFAS compounds were detected, but their concentrations were below their respective Method Quantification Limits (MQL) and were estimated. A study of background soil PFAS concentrations determined that the world median background is 2.7 µg/kg based on approximately 5700 soil samples from more than 1400 sampling locations across the world (Brusseau et al. 2020).

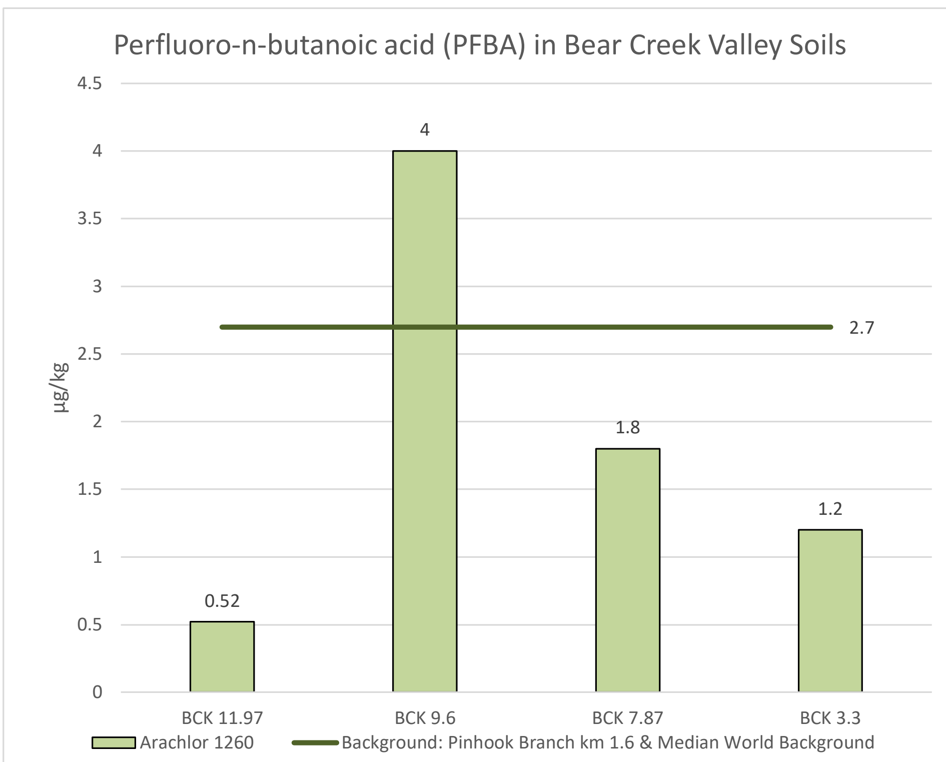


**Figure 10.1.30: Perfluoro-n-butanoic acid (PFBA) in Bear Creek Valley Soils**

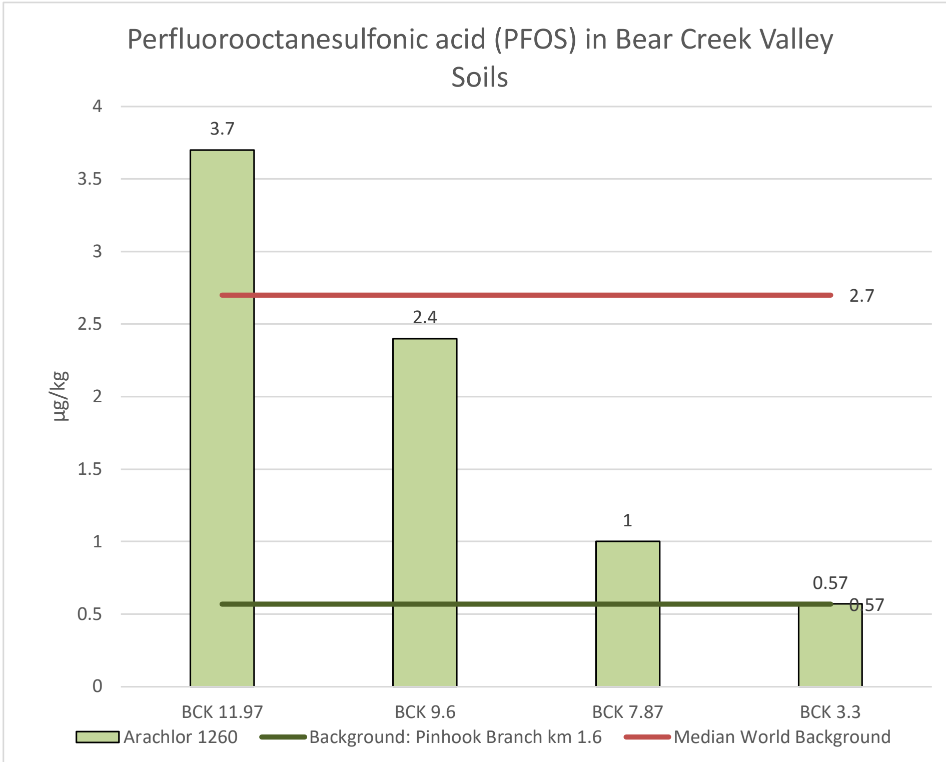


**Figure 10.1.31: Perfluorooctanesulfonic acid (PFOS) in Bear Creek Valley Soils**

Radiochemistry soils data revealed that uranium was the primary contaminant of concern in the Bear Creek Valley. Uranium and its daughters contributed to relatively high gross alpha values at the Bear Creek sites as compared to the PBK 1.6 background site (Figure 10.1.32). Gross beta activity at BCK 3.3 was less than that of the background site, PBK 1.6 (Figure 10.1.33). The differences in gross beta between the background site and the Bear Creek sites were not as pronounced as are the gross alpha activities. BCK 7.87 had the greatest gross beta activity with the other sites having activities that were close to background. Table 10.1.3 lists the activities of some other radionuclides present in the Bear Creek Valley soils. Some of the radionuclides in Table 10.1.3 exceeded the EPA soil screening levels (SSLs) for ingestion of home grown produce (USEPA 2000).

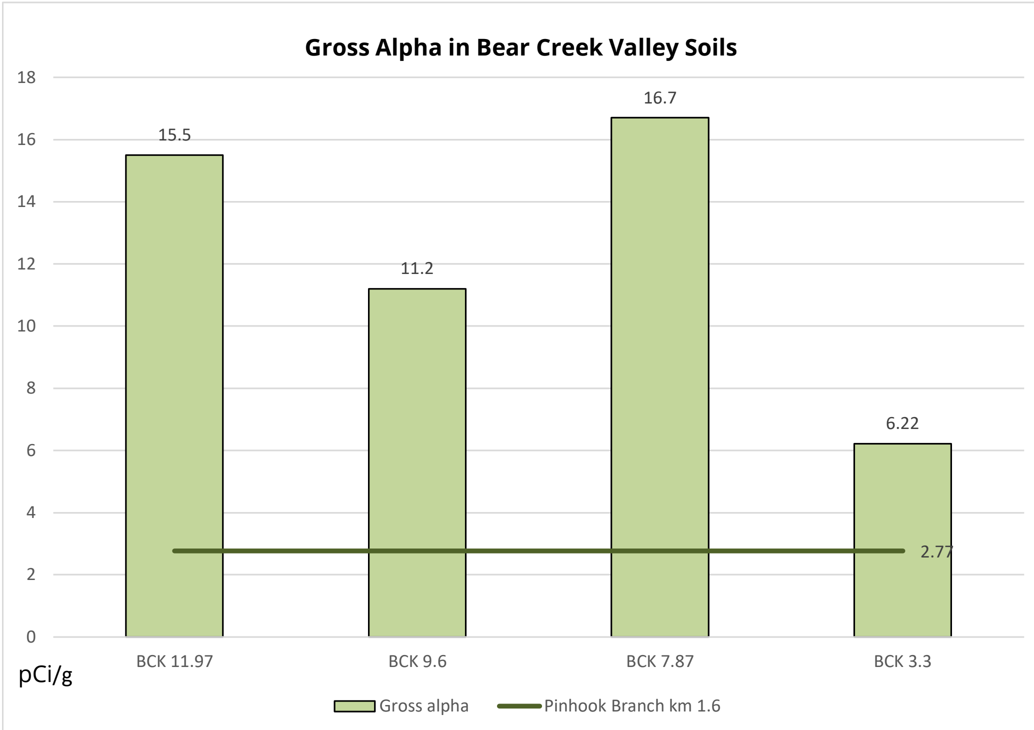


**Figure 10.1.32: Gross alpha in Bear Creek Valley Soils**

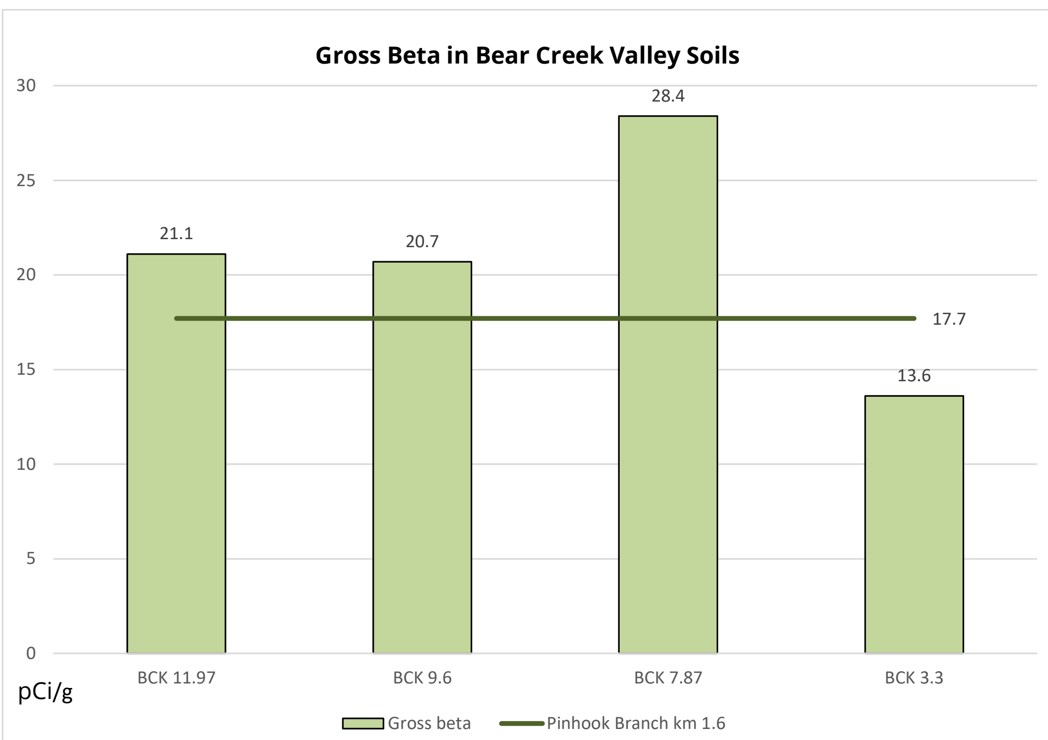


**Figure 10.1.33: Gross beta in Bear Creek Valley Soils**

Isotopic uranium data showed that the Bear Creek Valley soils have a depleted uranium signature, whereas the uranium at the background site was indicative of natural uranium (Figures 10.1.34-10.1.36).

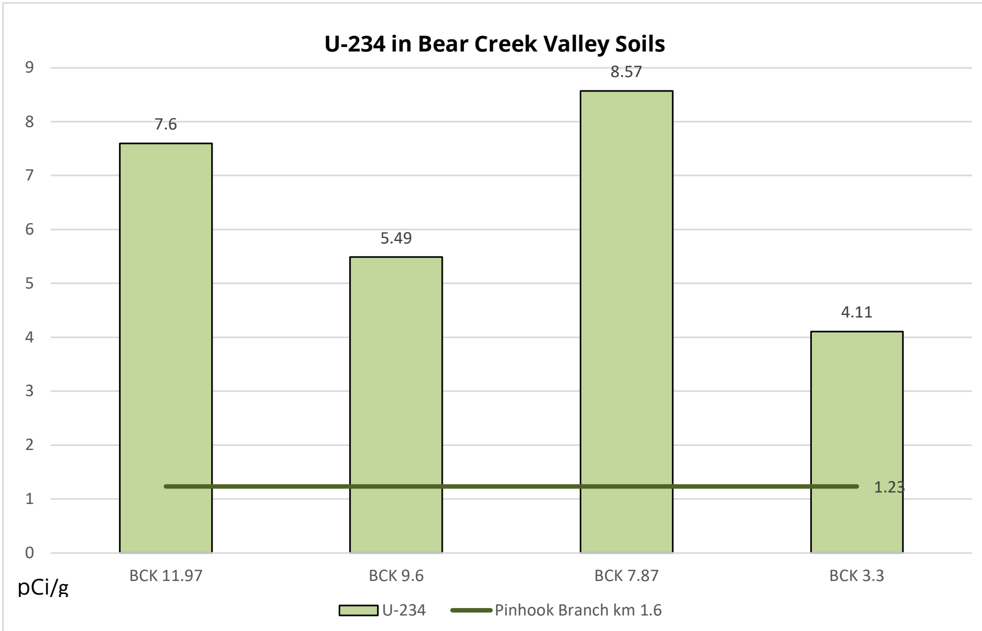


**Figure 10.1.34: U-234 in Bear Creek Valley Soils**

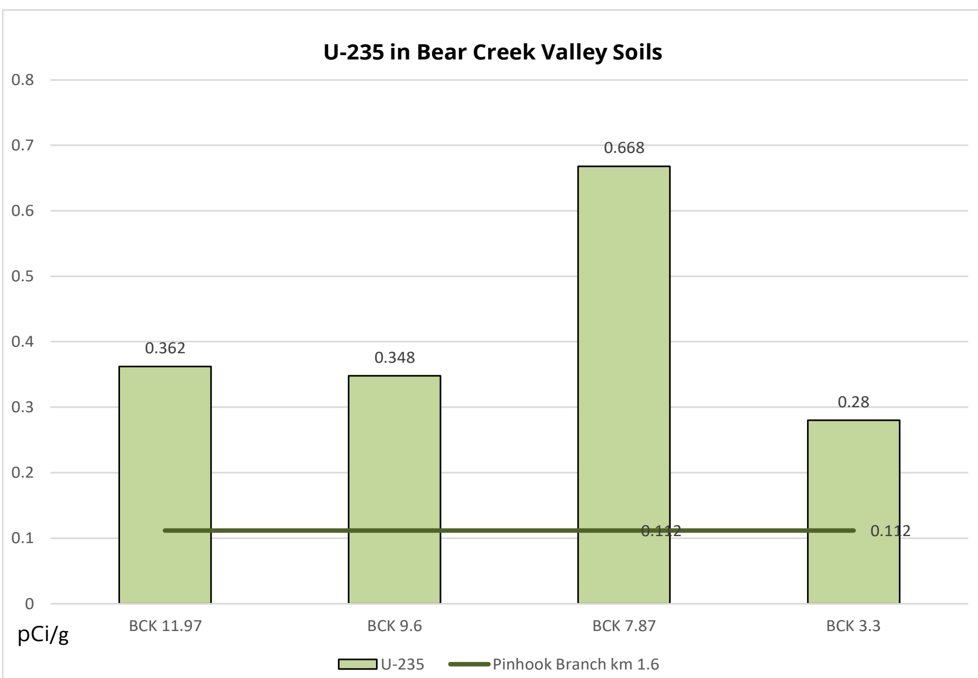


**Figure 10.1.35: U-235 in Bear Creek Valley Soils**

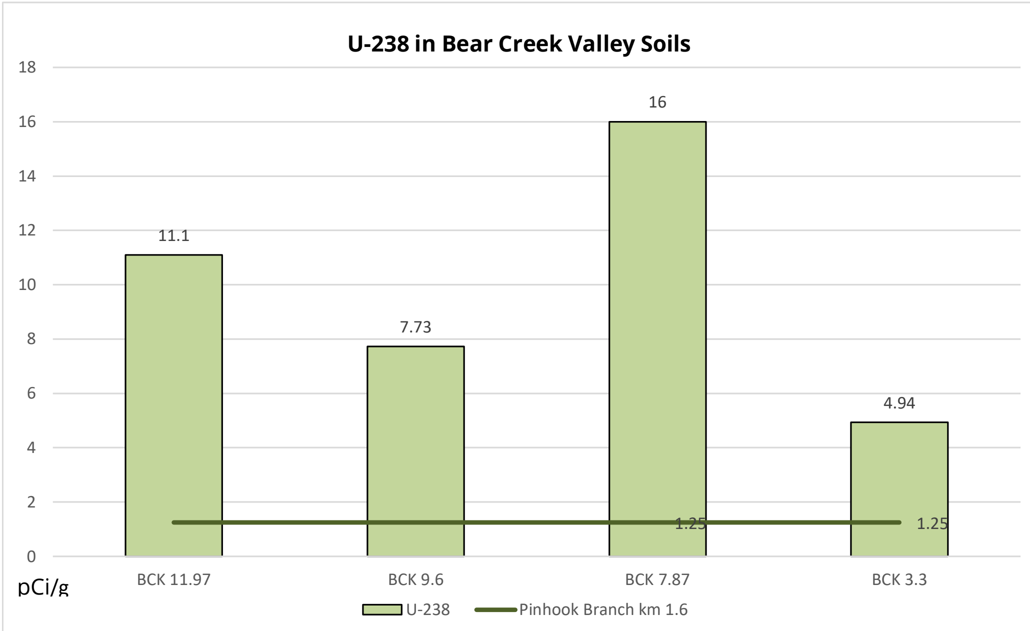


**Figure 10.1.36: U-238 in Bear Creek Valley Soils**

**Table 10.1.3: Radionuclide activities in Bear Creek Valley Soils**

| Radionuclide (pCi/g) | EPA SSLs Homegrown Produce | PBK 1.6 - background | BCK 11.97 | BCK 9.6 | BCK 7.87 | BCK 3.3 |
|---|---|---|---|---|---|---|
| Ac-228 | 0.0915 | 0.706 | 1.04 | 0.932 | 0.95 | 0.616 |
| Be-7 | – | U | U | U | U | U |
| Bi-212 | – | U | 1.22 (J) | 1.41 | 0.884 (J) | 1.11 |
| Bi-214 | 0.0688 | 0.906 | 0.805 | 0.838 | 0.716 | 0.64 |
| K-40 | 0.137 | 21.6 | 10.7 | 9.11 | 8.07 | 12.4 |
| Pb-212 | – | 0.926 | 1.28 | 1.07 | 0.923 | 0.853 |
| Pb-214 | – | 0.82 | 0.716 | 0.785 | 0.669 | 0.763 |
| Tl-208 | – | 0.279 | 0.387 | 0.346 | 0.271 | 0.257 |
| U-234 | 5.9 | 1.23 | 7.6 | 5.49 | 8.57 | 4.11 |
| U-235 | 5.77 | 0.112 | 0.362 | 0.348 | 0.668 | 0.28 |
| U-238 | 4.65 | 1.25 | 11.1 | 7.73 | 16 | 4.94 |
| Sr-89 | – | 0.722 | U | 0.367 (J) | U | 0.237 (J) |
| Sr-90 | 0.0689 | 0.618 | U | 0.315 (J) | U | 0.203 (J) |
| Americium-241 | 10.8 | 0.0838 (J) | 0.124 (J) | 0.932 | 0.168 (J) | U |

Yellow highlight indicates that reported activity exceeds soil screening levels (SSLs) for ingestion of home grown produce (EPA Soil Screening Guidance for Radionuclides).

J = estimated value

U = not detected in the analytical method's detectable limits

– = no SSL available

## Biota

### Fish

The original plan called for rock bass (*Ambloplites rupestris*) sampling at BCK 3.3, EFK 2.2, and MBK 1.6. The Oak Ridge National Laboratory's Environmental Sciences Division was able to provide a small sampling of sunfish from the background site, Hinds Creek km 20.6 (HCK 20.6) and BCK 3.3. The sample was adequate for only radiological analysis; no other tests could be conducted due to the small sample size at each of these locations. The sampling at both sites did not provide for samples of rock bass but did yield a small set of centrarchid fishes (sunfish) of various species, all of which are commonly consumed by humans when of sufficient size. Centrarchid (sunfish) filets were submitted to the Tennessee Department of Health Laboratory Services for analysis. The limited number of analyses included gamma spectroscopy, gross alpha-beta, Tc-99, and isotopic uranium. Potassium-40 (K-40) activity was detected at both the background site and at BCK 3.3 at 3.29 ± 0.86 and 4.1 ± 1.1 pCi/g, respectively. K-40 is a naturally occurring radionuclide that is found in the environment and in animals including humans. The only other parameter that was detected was gross beta at BCK 3.3 at 5 ± 1.3 pCi/g.

Note: For a radiological result to be considered detected, the CSU at 1-sigma should be less than or equal to 30 percent of the result value. If the CSU at 1-sigma is greater than 30 percent of the result, there is too much uncertainty associated with the result. The CSU is the statistical standard deviation of an individual radiological result. The concentration (or activity) and its associated CSU should not be interpreted as a single point, but as a confidence interval about the measured concentration in which one has a high statistical probability of finding the true concentration of the sample. The State of Tennessee Radiochemistry Laboratory calculates and reports the CSU at the 68-percent or 1-sigma confidence level. Reporting the concentration with its corresponding CSU at 1-sigma provides the 68-percent confidence interval; for example, 1.25 +/- 0.25 pCi/L would have a corresponding 68-percent confidence interval of 1.00 to 1.50 pCi/L. In other words, there is a 68-percent chance that the true value is between 1.00 and 1.50 pCi/L.

### Vegetation

Vegetation samples were collected and submitted to the laboratory for radiological analysis. Unfortunately, a laboratory device malfunctioned, and the samples were destroyed. There was not enough time to re-sample before the end of the fiscal year.

### Songbird Eggs

Songbirds' eggs were collected at BCK 12.3, 4.5, and at a background location. Eggs were not available for collection at the other sites. These samples were analyzed for radiochemistry parameters such as gross alpha, gross beta, uranium isotopic, strontium-89, -90, and technetium-99. All of the results were very low values with unacceptable levels of uncertainty. For a radiological result to be considered detected, the Combined Standard Uncertainty (CSU) at 1-sigma should be less than or equal to 30 percent of the result value. If the CSU at 1-sigma is greater than 30 percent of the result, there is too much uncertainty associated with the result.

### Adult Insects

Samples of adult insects were collected at BCK 12.3, 9.6, and at MBK 1.6 (background site). These samples were analyzed for radiochemistry parameters. All of the results were very low values with unacceptable levels of uncertainty. For a radiological result to be considered detected, the CSU at 1-sigma should be less than or equal to 30 percent of the result value. If the CSU at 1-sigma is greater than 30 percent of the result, there is too much uncertainty associated with the result.

### Spiders

Spider samples were captured from BCK 12.3, 4.5, and MBK 1.6. These samples were analyzed for radiochemistry parameters. All of the results were very low values with unacceptable levels of uncertainty. For a radiological result to be considered detected, the CSU at 1-sigma should be less than or equal to 30 percent of the result value. If the CSU at 1-sigma is greater than 30 percent of the result, there is too much uncertainty associated with the result.

### Benthic Macroinvertebrates

Benthic macroinvertebrate samples were collected at BCK 12.3, 9.6, 7.6, 4.5, 3.3 and at MBK 1.6. The following graphs of community metrics describe the differences among the sites sampled.

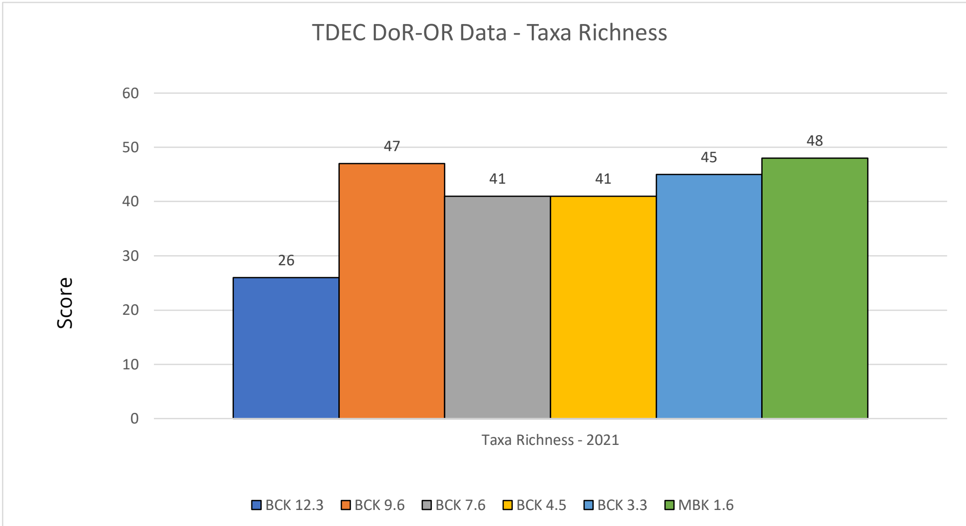


**Figure 10.1.37: Benthic macroinvertebrates – Taxa Richness**

Taxa richness is the total number of distinct genera found in the sample. A high score is desirable and indicates diversity of organisms and a variety of food types in the community. Food sources are adequate to support the survival and reproduction of many taxa. The background site, MBK 1.6, had the highest score with 48 genera; BCK 9.6 was a close second with 47 genera (Figure 10.1.37). The poorest site was BCK 12.3 which had marginally poor habitat with a hard clay substrate that was not optimal for colonization.

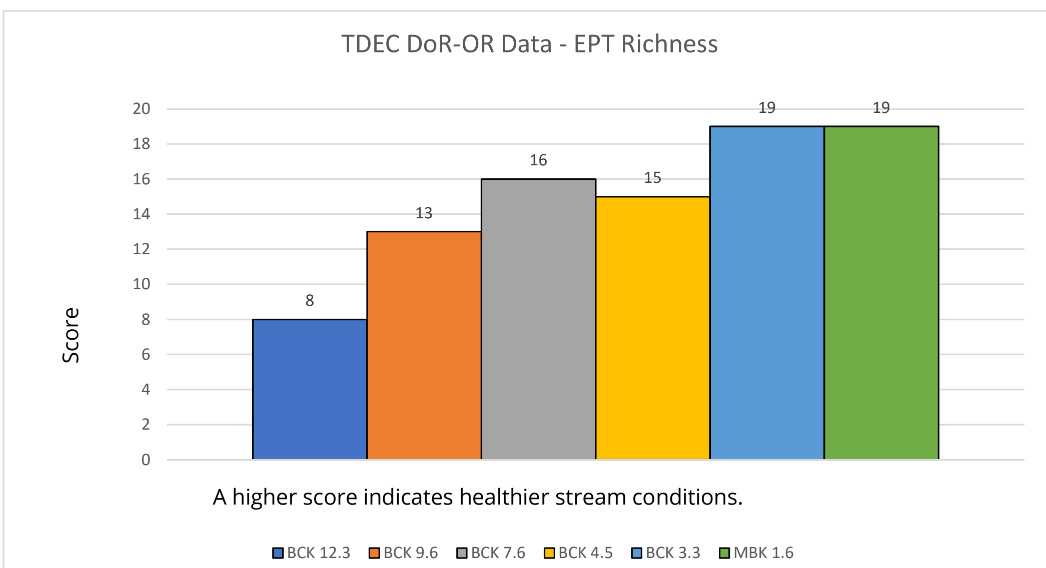


**Figure 10.1.38: Benthic macroinvertebrates: EPT Richness**

EPT richness is the total number of Ephemeroptera, Plecoptera, and Trichoptera genera in a sample. The EPT taxa are relatively intolerant of pollution and poor habitat, so their presence is a good sign and the more diversity in their population, the better. BCK 3.3 was tied with the background site, MBK 1.6 for the highest score (Figure 10.1.38). The upstream Bear Creek sites did not score well, particularly BCK 12.3.

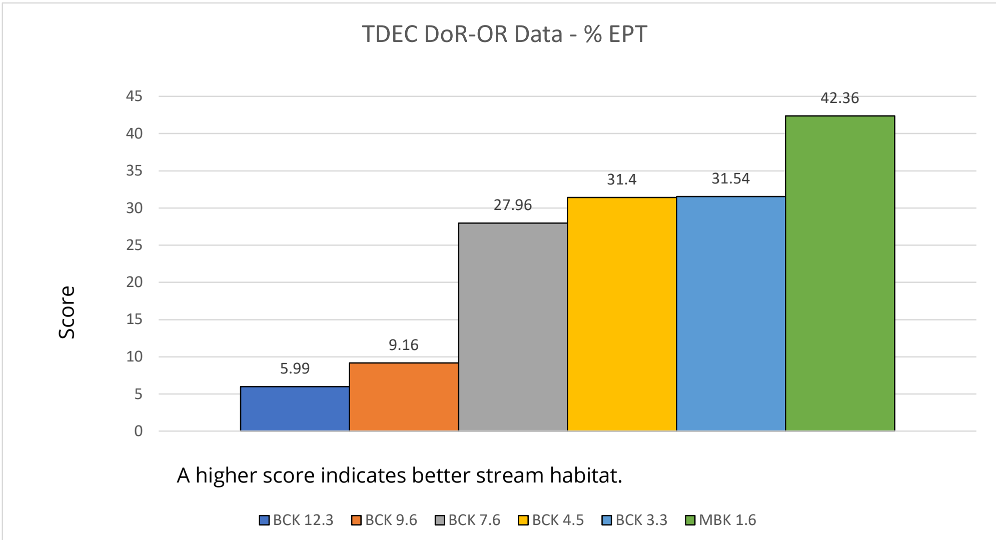


**Figure 10.1.39: Benthic macroinvertebrates: % EPT**

This metric (% EPT) measures the composite percentage of Ephemeroptera, Plecoptera, and Trichoptera taxa. These relatively intolerant insects are an indicator of good stream health, and a high score indicates a healthy stream. The most upstream site, BCK 12.3, scored poorly due to a lack of habitat in the channelized upper reaches (Figure 10.1.39). The substrate there was a hardpan clay bottom with few places for EPT species to colonize.

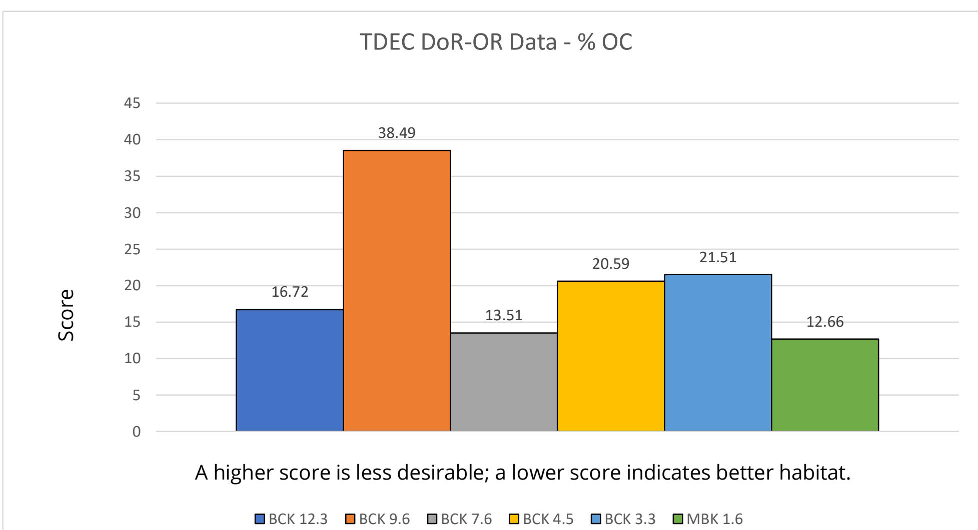


**Figure 10.1.40: Benthic macroinvertebrates: % OC**

Population stress due to poor water quality causes the % OC metric, percent of the composite of Oligochaeta (aquatic worms) and Chironomidae (midge larvae), number to increase. In recent years, BCK 12.3 has shown marked improvement with regards to the % OC metric. For this metric, a low score is a good indicator of stream health (Figure 10.1.40).

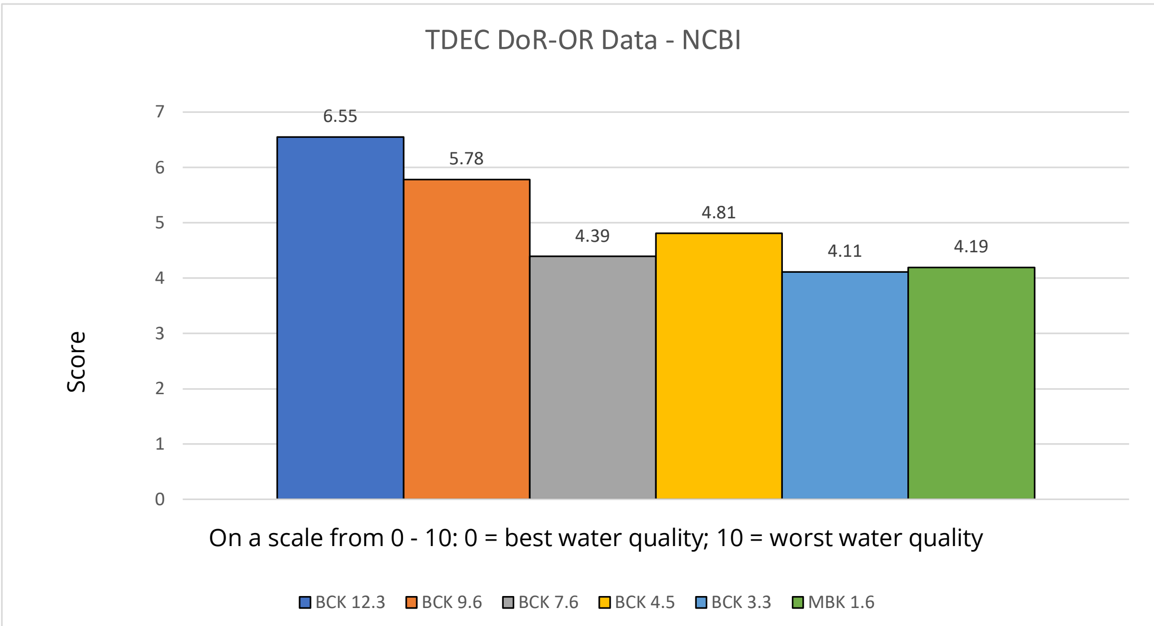


**Figure 10.1.41: Benthic macroinvertebrates – NCBI**

For the North Carolina Biotic Index (NCBI) metric, a lower score is an indication of more pristine stream conditions, and higher scores indicate more stressful conditions (Figure 10.1.41). The scores indicated the stream conditions improved with increased distance downstream of BCK 12.3. The NCBI is a weighted average of the tolerance values for the organisms identified from the sample in relation to their abundance. The NCBI value ranges from 0.0 to 10.0 and represents the tolerance of the benthic community to environmental stressors (NCDEQ 2016).

The "% clingers" metric is defined as the percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water. The % Clinger's data showed impairment at the two most upstream sites, BCK 12.3 and 9.6 (Figure 10.1.42). This was partly due to habitat alterations in the form of channelization of the stream at BCK 12.3 and a lack of habitat at 9.6. At BCK 12.3, the stream bed resembled a ditch with a hard clay substrate with few habitat opportunities for clingers.

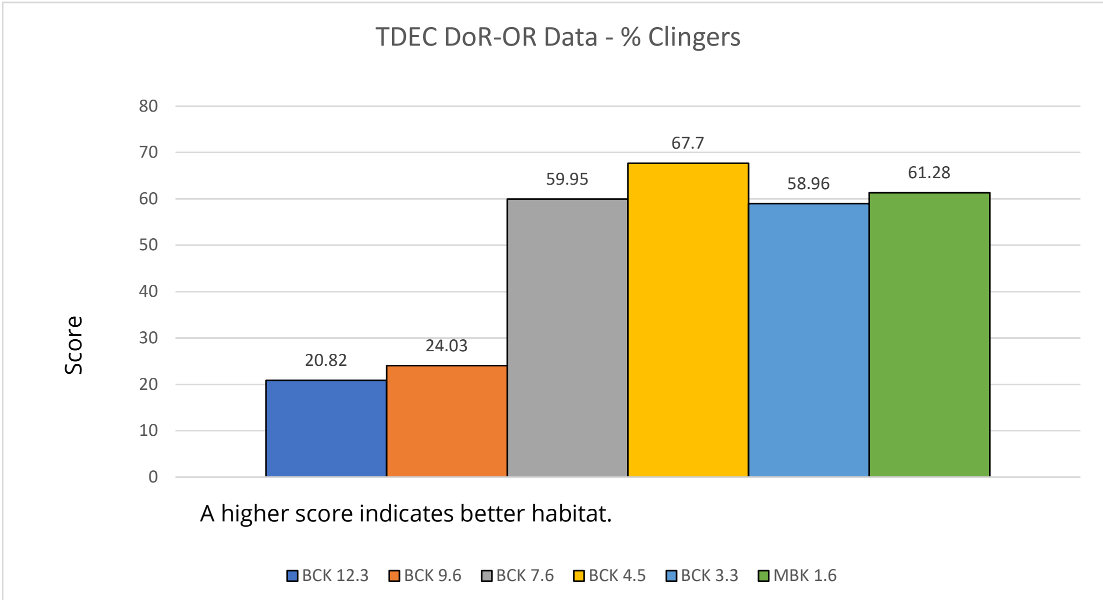


**Figure 10.1.42: Benthic macroinvertebrates - % Clingers**

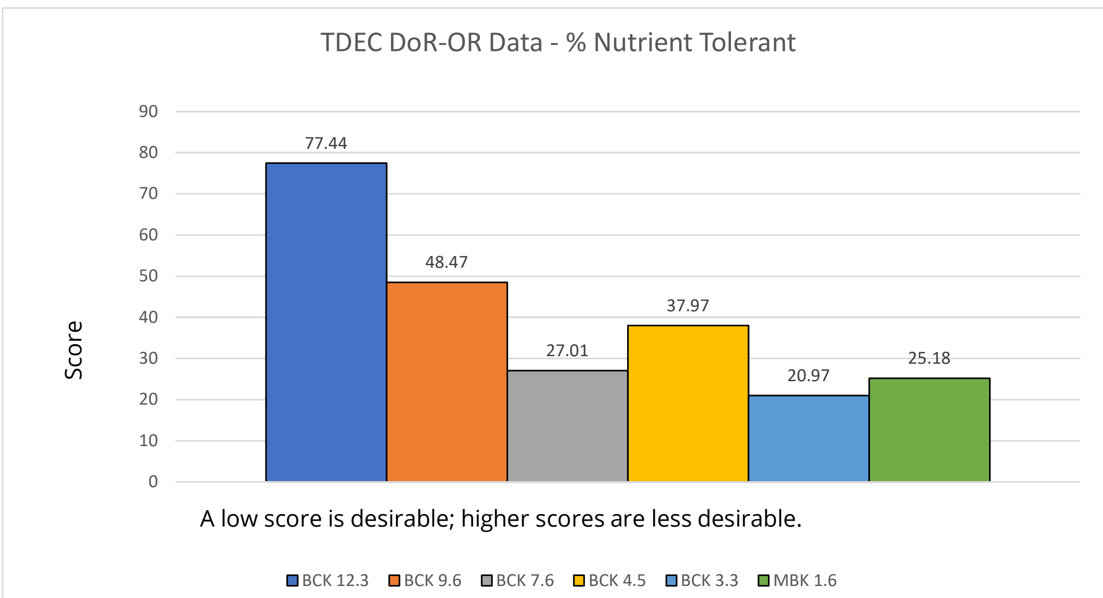


**Figure 10.1.43: Benthic macroinvertebrates - % Nutrient Tolerant**

This metric represents the percent of macrobenthos considered to be tolerant of perturbation by the presence of moderate to high levels of nutrients in the stream. Nitrate pollution of Bear Creek is present at BCK 12.3; shallow groundwater contributes nitrate contamination emanating from the former S-3 Ponds site (Figure 10.1.43). This nitrate addition may be the reason for the poor score with this metric at BCK 12.3. BCK 3.3 scored better than the background site (MBK 1.6) for this metric.

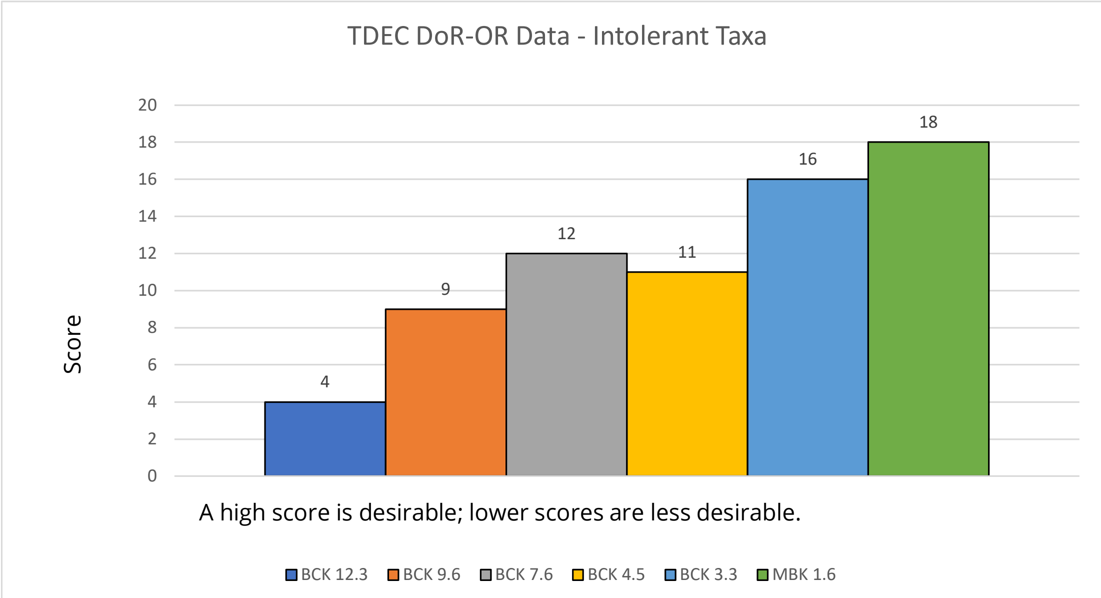


**Figure 10.1.44: Benthic macroinvertebrates – Intolerant taxa**

This metric represents the number of macrobenthos taxa present in the sample that are considered to be intolerant of perturbation of the stream in general. For this metric, the upstream sections scored poorly with scores increasing downstream. The background site, MBK 1.6 had the highest score (Figure 10.1.44).

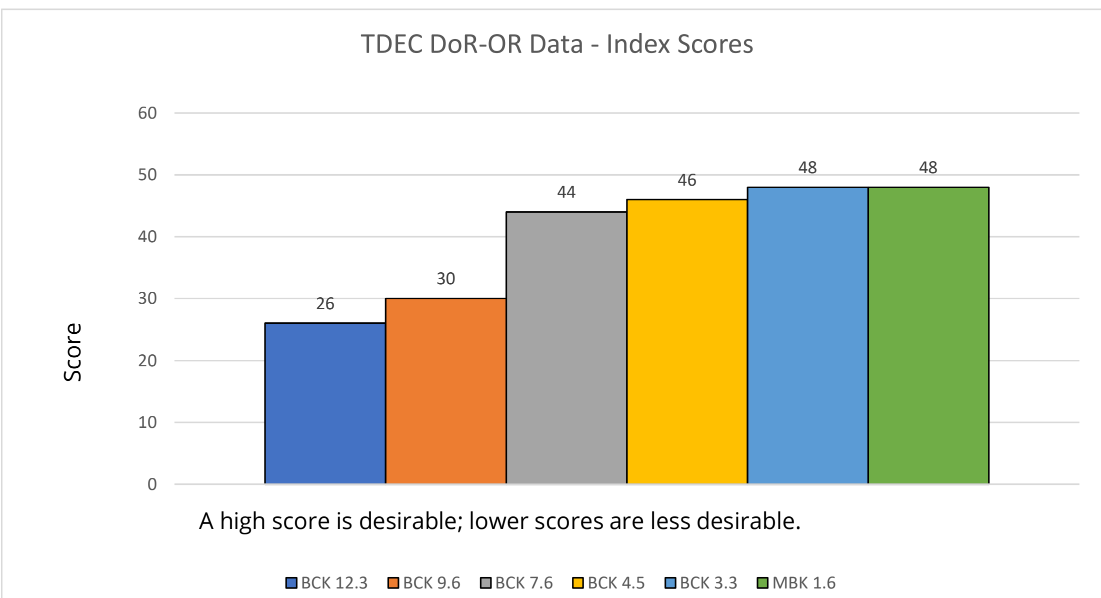


**Figure 10.1.45: Benthic macroinvertebrates – TMI Scores**

The Tennessee Macroinvertebrate Index (TMI) score for each site incorporates the results of eight different metrics to derive a composite score. This score serves as a rating for the stream that serves as a mean for comparison of the stream conditions among several sites. The components of the TMI are listed in Table 10.1.4. Calculations of the TMI scores (Tables 10.1.5-10.1.10) for the stream sites revealed that the two most upstream sites, BCK 12.3 and 9.6, are partially supporting/slightly impaired (TMI = 21-31) (Figure 10.1.45). All of the other sites were rated as supporting/non-impaired (TMI >=32).

**Table 10.1.4: Tennessee Macroinvertebrate Index components**

| TMI Rating Components | | | | |
|---|---|---|---|---|
| **Metric** | **6** | **5** | **2** | **0** |
| **Taxa Richness** | >38 | 25-37 | 12-24 | <12 |
| **EPT Richness** | >14 | 9-13 | 4-8 | <4 |
| **%EPT – Chem** | >30.61 | 20.41-30.60 | 9.80-20.40 | <9.80 |
| **%OC** | <=45.39 | 45.40-63.59 | 63.60-81.79 | >81.79 |
| **NCBI** | <=4.99 | 5.00-6.69 | 6.70-8.33 | >8.33 |
| **%Clingers** | >26.77 | 17.85-26.76 | 8.01-17.84 | <8.01 |
| **%NUTOL** | <=39.43 | 39.44-59.62 | 59.63-79.81 | >79.82 |
| **%Intolerant Taxa** | >=15 | 11-14 | 8-10 | <8 |

**Table 10.1.5: TMI Stream Rating Results for BCK 12.3**

| **Alternative Reference Stream Metrics** | | **BCK 12.3** |
|---|---|---|
| Taxa Richness | 26 | 4 |
| EPT Richness | 8 | 2 |
| %EPT-CHEUM | 5.99% | 4 |
| %OC | 16.72% | 6 |
| NCIB | 6.55 | 4 |
| %Clingers | 20.82% | 4 |
| %TNutol | 77.44% | 2 |
| Intolerant Taxa | 4 | 0 |
| **Total** | | 26 |

**Table 10.1.6: TMI Stream Rating Results for BCK 9.6**

| Alternative Reference Stream Metrics | | BCK 9.6 |
|---|---|---|
| Taxa Richness | 47 | 6 |
| EPT Richness | 13 | 4 |
| %EPT-CHEUM | 9.16% | 0 |
| %OC | 38.49% | 6 |
| NCIB | 5.78 | 4 |
| %Clingers | 24.03% | 4 |
| %TNutol | 48.47% | 4 |
| Intolerant Taxa | 9 | 2 |
| **Total** | | 30 |

**Table 10.1.7: TMI Stream Rating Results for BCK 7.6**

| Alternative Reference Stream Metrics | | BCK 7.6 |
|---|---|---|
| Taxa Richness | 41 | 6 |
| EPT Richness | 16 | 6 |
| %EPT-CHEUM | 27.96% | 4 |
| %OC | 13.51% | 6 |
| NCIB | 4.39 | 6 |
| %Clingers | 59.95% | 6 |
| %TNutol | 27.01% | 6 |
| Intolerant Taxa | 12 | 4 |
| **Total** | | 44 |

**Table 10.1.8: TMI Stream Rating Results for BCK 4.5**

| Alternative Reference Stream Metrics | | BCK 4.5 |
|---|---|---|
| Taxa Richness | 41 | 6 |
| EPT Richness | 15 | 6 |
| %EPT-CHEUM | 31.40% | 6 |
| %OC | 20.59% | 6 |
| NCIB | 4.81 | 6 |
| %Clingers | 67.70% | 6 |
| %TNutol | 37.97% | 6 |
| Intolerant Taxa | 11 | 4 |
| **Total** | | 46 |

**Table 10.1.9: TMI Stream Rating Results for BCK 3.3**

| Alternative Reference Stream Metrics | | BCK 3.3 |
|---|---|---|
| Taxa Richness | 45 | 6 |
| EPT Richness | 19 | 6 |
| %EPT-CHEUM | 31.54% | 6 |
| %OC | 21.51% | 6 |
| NCIB | 4.11 | 6 |
| %Clingers | 58.96% | 6 |
| %TNutol | 20.97% | 6 |
| Intolerant Taxa | 16 | 6 |
| **Total** | | 48 |

**Table 10.1.10: TMI Stream Rating Results for MBK 1.6**

| Alternative Reference Stream Metrics | | MBK 1.6 |
|---|---|---|
| Taxa Richness | 48 | 6 |
| EPT Richness | 19 | 6 |
| %EPT-CHEUM | 42.36% | 6 |
| %OC | 12.66% | 6 |
| NCIB | 4.19 | 6 |
| %Clingers | 61.28% | 6 |
| %TNutol | 25.18% | 6 |
| Intolerant Taxa | 18 | 6 |
| **Total** | | 48 |

### 10.1.8 Conclusions

Uranium is the primary metal of concern in Bear Creek sediments; uranium is 6.8- and 13.8-times background at NT-5 and BCK 3.3, respectively. There are no established CBSQGs for uranium at the present time. Sediment concentrations of mercury and cadmium are very slightly above the TEC at BCK 3.3. Combined effects of metals above the TEC may work together to negatively impact the stream. The other individual metals are not posing a threat to the stream environment.

Sediment gross alpha activity appears to have decreased over the last six years at NT-5. In 2021, the gross alpha activity was below the three-year (2018, 2019, 2021) mean for the Mill Branch background site. Gross beta activity has increased greatly at NT-5 since 2019, perhaps as a result of recent disposal of Tc-99-containing wastes at EMWMF. U-234 and U-235 activity is greatest at NT-5, decreasing downstream. U-238 activity is greatest at BCK 7.6, with slightly less activity at BCK 3.3.

The primary surface water contaminants of concern are nitrate and uranium (Figures 10.1.15, 10.1.16). Arsenic, cadmium, chromium, selenium, and zinc were not detected in Bear Creek surface water and a trace of copper (0.31 μg/L) was found only at BCK 12.3. Mercury was detected at BCK 12.3 and 9.6 but only in trace amounts and much less than the Tennessee Water Quality Criteria (0.051 μg/L).

Surface water gross alpha activity exceeds the EPA MCL of 15 pCi/L at BCK 12.3 (Figure 10.1.17). As Bear Creek does not have a designated use as a drinking water source, the MCL is used for comparison. This gross alpha activity can be attributed to the uranium in the creek water. The influx of uranium-contaminated shallow groundwater from the former S-3 ponds site explains the high gross alpha activity seen at BCK 12.3.

Surface water gross beta activity is elevated at BCK 12.3 and BCK 9.6 from at least two sources. One source, the S-3 Ponds site, was where uranium and other radionuclides were disposed of in four unlined ponds. These ponds were stabilized and capped with a RCRA cap over the area and covered with asphalt to make a parking lot in 1988, but there were large releases. Another source is the Bear Creek Burial Grounds, which add to the contribution at BCK 9.6. Both the U-238 and U-235 decay series produce several beta-emitting daughter nuclides with very short half-lives, (e.g., Bi-214 and Pb-214) and thus are radioactive in surface water at BCK 9.6 and BCK 12.3. Technetium-99 may also be contributing to the elevated gross beta activity there.

None of the semivolatile results in soils exceeded the U.S. EPA's Regional Screening Levels (RSLs) for residential direct contact exposure with a target cancer risk of $10^{-6}$ and a target hazard quotient of 0.1. Pesticide analysis showed no detections above the method detection limits (MDLs). PCBs were not detected at PBK 1.6; arochlor 1260 was quantified in each of the Bear Creek sites at a level below the EPA RSLs for residential soil under the direct contact exposure scenario.

Arsenic and uranium were detected in soil at levels above the RSLs for residential under direct contact exposure in all of the samples (Figures 10.1.26, 10.1.27). At PBK 1.6, the arsenic value was estimated. At BCK 11.97, the mercury concentration exceeded the RSL (Figure 10.1.28). Cadmium at the Bear Creek sites was considerably higher than background but below the RSL for soil direct contact (Figure 10.1.29).

Several PFAS compounds were detected in all of the soil samples. Perfluoro-n-butanoic acid (PFBA) was present at all sites, with an estimated value at BCK 11.97. The site with the greatest concentration of PFBA was BCK 9.6 (4 μg/kg). Perfluorooctanesulfonic acid (PFOS) was also detected in all of the samples, with estimated values for PBK 1.6 and BCK 3.3. The maximum concentration of PFOS was found at BCK 11.97 (3.7 μg/kg).

Uranium and its radionuclide daughters contribute to relatively high gross alpha soil values at the Bear Creek sites as compared to the PBK 1.6 background site (Figure 10.1.32). Gross beta activity at BCK 3.3 is less than that of the background site, PBK 1.6 (Figure 10.1.33). BCK 7.87 has the greatest gross beta activity with the other sites having activities that are close to background. Some of the radionuclides in Table 10.1.3 exceed the EPA soil screening levels (SSLs) for ingestion of home grown produce (USEPA 2000).

Isotopic uranium data show that the Bear Creek Valley soils have a depleted uranium signature, whereas the uranium at the background site has a U-234/U-238 ratio that is indicative of natural uranium.

Reproduction of *Ceriodaphnia dubia* was inhibited at BCK 12.3; the IC25 was 26.8%, meaning that the addition of 26.8% of stream effluent caused a 25% reduction in *Ceriodaphnia dubia* reproduction. All of the other sites had an IC25 of (>)100%, which means that survival and reproduction of *Ceriodaphnia dubia* were not inhibited by the Bear Creek water.

Pimephales promelas (fathead minnow) was used for testing survival and growth at the same sampling sites. Inhibition was demonstrated at three sites: BCK 12.3, BCK 3.3, and EFK 2.2. At BCK 12.3, the IC25 is reported as being greater than (>) 100% effluent for survival and equal to 77.3% effluent for growth. The overall IC25 is reported as being the lesser of the two values (77.3% effluent). At BCK 3.3, the IC25 is 39.3%, which is the value for growth; the IC25 survival value was (>)100%. The worst performing site was EFK 2.2, with a IC25 of 21.8% (growth); the IC25 for survival here was 56.3%. EFK 2.2 samples were collected at the mouth of Bear Creek (Bear Creek kilometer 0.0).

The benthic macroinvertebrate sampling revealed that BCK 12.3 and 9.6 are slightly impaired in terms of supporting a healthy community. All of the stream sites from BCK 7.6 and downstream are non-impaired. BCK 3.3 had the same TMI rating (48) as the background site, MBK 1.6. Other biota results will be discussed after analyses are complete and the results are received.

### 10.1.9 Recommendations

Further sampling is warranted in the Bear Creek Valley in order to monitor for changes to the environment, especially once construction begins on EMDF and the new landfill becomes operational. Changes in surface water must be tracked and recorded to observe any trends that may develop with regard to contaminant levels in Bear Creek. Sediment sampling must continue to detect changes in contaminants being transported in the stream.

## 10.1.10 References

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